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An Economic Assessment of STOL Aircraft Potential Including Terminal Area Environmental Considerations

Volume II: Appendices

Prepared by H. L. SOLOMON and S. SOKOLSKY
Air Transportation Group

July 1973

Prepared for AMES RESEARCH CENTER
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Moffett Field, California 94035

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VOLUME II : APPENDICES

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FOREWORD

This report on an economic assessment of STOL aircraft potential including terminal area environmental considerations is published in two volumes. Volume I presents the findings in seven sections:

- Summary
- Introduction
- Approach
- STOL System Characteristics
- Arena Descriptions
- Results
- Conclusions

This document, Volume II, contains appendices with supporting reference data and methodology as follows:

- Appendix A: STOL System Characterization
- Appendix B: Arena Characterization
- Appendix C: Transportation System Simulation
- Appendix D: Supplementary Results

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This study, performed for the Ames Research Center under NASA Contract No. NAS 2-6473, is part of the NASA study of V/STOL aircraft applications as a possible means of solving the growing air transportation problems in the U. S. The present study evaluated the economic viability and environmental compatibility of STOL service in short haul high density arenas. Appreciation is extended to Mr. George Kenyon and Mr. Elwood Stewart, the NASA Technical Monitors of the study, for their assistance and guidance provided.

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CONTENTS

Page No.

APPENDIX A: STOL SYSTEM CHARACTERIZATION A-1

APPENDIX B: ARENA CHARACTERIZATION B-1

APPENDIX C: TRANSPORTATION SYSTEM SIMULATION C-1

APPENDIX D: SUPPLEMENTARY RESULTS D-1

GLOSSARY Gl-1

REFERENCES R-1

VOLUME II

APPENDIX A

STOL SYSTEM CHARACTERIZATION

CONTENTS

			Page No.
A. 1	Short Takeoff and Landing (STOL) Aircraft Description		A-1
	a.	Concept	A-1
	b.	Physical Characteristics	A-2
	c.	Performance	A-5
	d.	Noise	A-14
	e.	Pollution	A-37
A. 2	STOLport Requirements		A-45
	a.	Airfield	A-47
	b.	Terminal	A-47
	c.	Noise Buffer Zones	A-51
A. 3	Economic Analysis		A-61
	a.	Aircraft Unit Costs	A-61
	b.	Direct Operating Costs	A-68
	c.	Indirect Operating Costs	A-72
	d.	Port-Related Indirect Operating Costs	A-81
	e.	Total Operating Costs	A-85
	f.	Return on Investment	A-85

FIGURES

A-1.	Augmentor Wing, Propulsion Concept	A-2
A-2.	General Configuration, Two-Stream Augmentor Wing Airplane	A-3
A-3.	Design Data	A-5
A-4.	Turnaround Times	A-11
A-5.	Extended-Range Aircraft Passenger Capacity	A-13
A-6.	Augmentor Duct, Nozzle, Flap, and Structure Integration	A-16
A-7.	Multiple Pure Tone Noise from Supersonic Dip Speed Fans	A-18
A-8.	Sonic Inlet (Choking) Concept	A-19
A-9.	Sonic Inlet Performance	A-20

FIGURES (Continued)

Page No.

A-10.	Fan Approach Noise, Unsuppressed	A-20
A-11.	Jet Noise Comparison	A-22
A-12.	STF-344 Sea-Level Data	A-22
A-13.	Augmentor Noise Reduction Development	A-24
A-14.	Augmentor Noise Contribution	A-25
A-15.	Effect of Flow Turning on PNL Beam Pattern	A-27
A-16.	Effect of Flow Turning on Spectral Noise Content	A-27
A-17.	Augmentor System Noise Performance, 150-Passenger Aircraft	A-28
A-18.	Atmospheric Effects on Propagation of Noy-Weighted Spectra	A-32
A-19.	Atmospheric Absorption per 1000 feet, Standard Day	A-32
A-20.	Atmospheric Attenuation of Noy-Weighted Spectrum	A-33
A-21.	Duration Corrections versus Distance	A-34
A-22.	Transfer Function Relating EPNL to Peak PNL	A-35
A-23.	Conversion of PNL at 500 feet to EPNL vs Slant Range	A-36
A-24.	Augmentor Wing Aircraft Noise, 20° to 35° of Flap	A-36
A-25.	Specific Pollution Index (lb/sec Pollutant/100,000-lb Rated Thrust)	A-41
A-26.	Takeoff Taxi Time Effects	A-46
A-27.	Design Curves, Flexible Pavement, Dual - Tandem Gear	A-48
A-28.	Terminal Building Area Requirements, FAA Data	A-50
A-29.	Gate Capacity Limits	A-52
A-30.	Sacramento Executive Airport Area	A-58
A-31.	Sacramento Executive Airport	A-60
A-32.	Sacramento Executive Airport Land Uses	A-60
A-33.	Economic Model Data Flow	A-62
A-34.	Cost-Estimating Relationships	A-65
A-35.	Augmentor Wing Aircraft, Direct Operating Costs	A-72
A-36.	California Corridor Indirect Operating Costs	A-76

FIGURES (Continued)

Page No.

A-37. Northeast Corridor/Midwest Triangle Indirect Operating Costs A-79

TABLES

A-1 Aircraft Design Geometry A-6
A-2 Aircraft Block Performance A-7
A-3 Augmentor Wing Aircraft Performance Parameters A-8
A-4 Aircraft Turnaround Time (Two-door Configuration) A-10
A-5 Extended-Range Augmentor Wing Parameters A-12
A-6 Augmentor Wing Aircraft Engine Comparison A-17
A-7 Inlet Noise, 500-foot Sideline A-21
A-8 Core Jet Noise, 500-foot Sideline A-23
A-9 Augmentor System Noise, 500-foot Sideline A-26
A-10 Noise Source Contributions 500-foot Sideline A-29
A-11 Perceived Noise Level, 500-foot Slant Range, 150-Passenger Augmentor Wing Aircraft A-30
A-12 Spatial Variation of Augmentor Wing Noise A-30
A-13 Engine Emission Indices A-38
A-14 Allison PD287-43 Turbofan Engine Parameters A-40
A-15 Landing and Takeoff Cycles for Turbine-Powered Aircraft . A-42
A-16 Turbofan Design Effects A-43
A-17 LTO-Cycle Effects A-44
A-18 Emission Levels and 1979 EPA Goals A-45
A-19 CTOL/STOL Differences A-45
A-20 Airframe - Development and Manufacturing Costs A-64
A-21 Engine Unit Cost A-67
A-22 Augmentor Wing STOL Flyaway Cost A-67
A-23 California Corridor Indirect Operating Cost A-75
A-24 Northeast/Midwest IOC Method and Rationale A-77
A-25 IOC Comparison - Common Elements A-78

TABLES (Continued)

		Page No.
A-26	Northeast/Midwest Indirect Operating Costs	A-80
A-27	STOL Operating Costs	A-86
A-28	ROI Equivalence	A-87

APPENDIX A

STOL SYSTEM CHARACTERIZATION

The STOL aircraft concept selected by NASA as the basis for this study is an Augmentor Wing incorporating materials, propulsion technologies, and design practices believed to be commensurate with an economically viable and environmentally acceptable aircraft system. The physical characteristics and performance data describing these aircraft were furnished by the NASA Ames Research Center and subsequently developed into parametric form as a function of vehicle size by The Aerospace Corporation. The methodology employed in subsequent system analyses required the development of only a few aircraft parameters, but these parameters in turn combine many factors related to both design and operations. As an example, the block time experienced by an aircraft in airline service is an accumulation of times for taxi and takeoff, climb to altitude, cruise, descend from altitude, land, and taxi to the arrival gate. Trajectories influence not only block time and fuel requirements but pollution emissions and noise impact on land surrounding the terminal area as well. Aircraft turnaround time, although not a traditional performance parameter, influences annual aircraft utilization rates and, hence, investment amortization: it further affects airport gate requirements and, hence, landing fees.

A.1 SHORT TAKEOFF AND LANDING (STOL) AIRCRAFT DESCRIPTION

a. Concept

The Augmentor Wing STOL concept utilizes a sophisticated system of wing flaps, for deflecting engine thrust, plus a unique system of boundary layer control to inhibit flow separation and to help redirect the free stream flow. A large portion of the air from the engine fans is ducted through the wing to a manifold forward of the flap, where the air is directed by a series of nozzles into the inlet formed by the upper and lower sections of the deflected flap.

The flaps deflect the primary jet downward and, through proper contouring and slotting of the forward flap segments, induce additional air to flow through the flap, augmenting the thrust of the primary jet and giving rise to the name of the concept. Boundary layer control can be applied near the leading edge of the wing to prevent leading-edge flow separation. A schematic view of the concept is shown in Figure A-1. The ducts from the engines to the flaps are interconnected across the aircraft fuselage to maintain a symmetrical lift distribution in the event of an engine failure. Since a significant portion of the thrust is produced by the cross-ducted secondary flow from the wing, the engine-out yawing moments are small. In normal cruise flight with flaps retracted, the fan flow is exhausted through a cruise nozzle.

b. Physical Characteristics

A design that typifies Augmentor Wing technology is shown in Figure A-2. A family of such 4-engine aircraft in four sizes from 50 to 200 passengers was defined by NASA. The NASA-supplied data have been

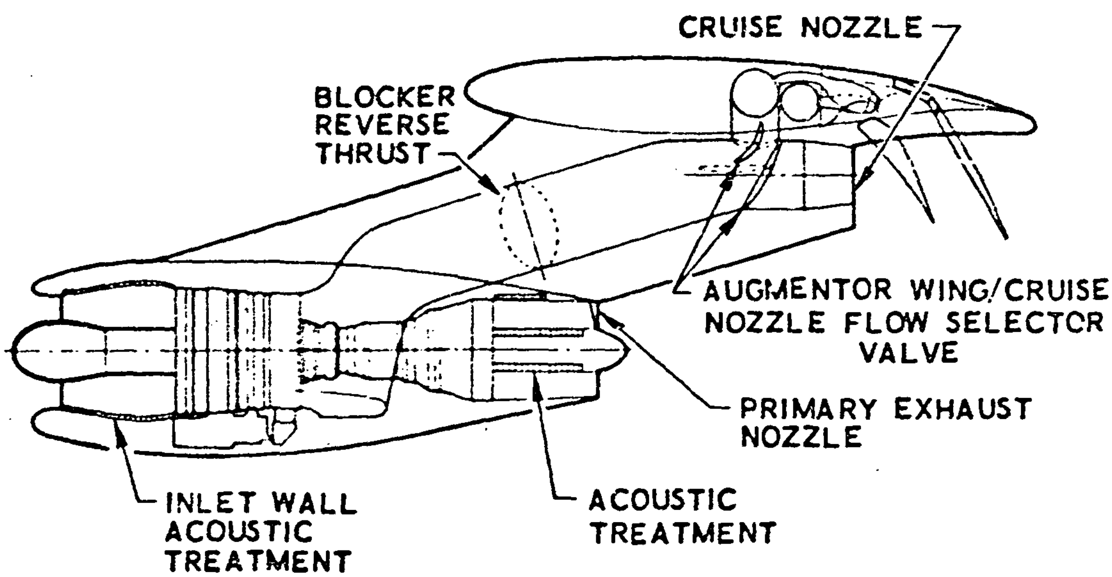
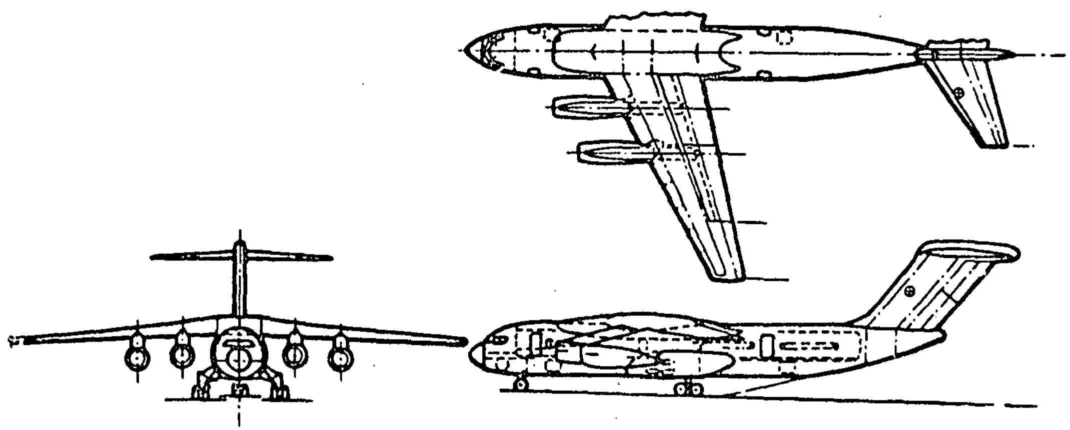


Figure A-1. Augmentor Wing, Propulsion Concept



NUMBER OF PASSENGERS	50	100	150	200
FUSELAGE LENGTH, ft	70	105	132	159
FUSELAGE WIDTH, ft	12	14	14	14
WING SPAN, ft	69	94	112	128
OPERATING EMPTY WEIGHT, lb	34,710	61,927	87,324	113,408
PAYLOAD (w/o fuel), lb	11,000	22,000	33,000	44,000
TAKEOFF GROSS WEIGHT, lb	54,801	100,000	142,782	186,169
THRUST/ENGINE, lb	5,875	10,715	15,300	19,950

Figure A-2. General Configuration, Two-Stream Augmentor Wing Airplane

interpolated to define an aircraft family for passenger capacities of from 50 to 200 in increments of 10. The Federal Air Regulation (FAR) field-length capability was 2,000 feet hot day, and the vehicles were designed for a 500-SM range, plus reserves*. In formulating the performance characteristics of this family of aircraft, NASA assumed the use of weight-reducing composite materials in wing, fuselage, and both horizontal and vertical stabilizers. The airframe materials consisted of 85-percent aluminum and 15-percent advanced low-weight composites. Engine and nacelle acoustic treatment, with the potential for limiting noise to less than 95 EPNdB at a 500-foot sideline distance, were incorporated into the designs. These characteristics are not unlike designs developed by Boeing under contract to NASA (Ref. 1 and 2). A major difference between the Boeing and NASA designs, however, is the latter's use of the Allison PD287-43, two-stream engine with cold/hot thrust split ratio of 86/14 in place of a proposed Pratt and Whitney advanced engine concept. The resulting NASA-designed aircraft requires less thrust per engine and results in a significant overall reduction in total aircraft weight for a given passenger capacity. Cruise Mach number is maintained at 0.8 at 30,000 feet.

The NASA design studies were performed using a version of the Boeing VASCOMP II V/STOL Aircraft Sizing and Performance Computer Program (Ref. 3). Sensitivity studies of Augmentor Wing aircraft designs with regard to such parameters as wing aspect ratio, sweep, thickness/chord ratio, etc. were originally performed by Boeing. Subsequent modification by NASA increased the aspect ratio from 6.5 to 7 and reduced wing loading from 87 to 80 psf. Important results of NASA's aircraft sizing effort are summarized in Figure A-2 for each of the four aircraft sizes considered by NASA. Gross weight and operating-weight-empty sensitivities to vehicle size are also plotted in Figure A-3. Detailed design geometry is contained in Table A-1.

*Reserves are defined as the additional fuel needed for 200 nautical miles of flight at 20,000 feet at cruise speed, plus that needed for 15 minutes of flight at 10,000 feet at 250 knots EAS.

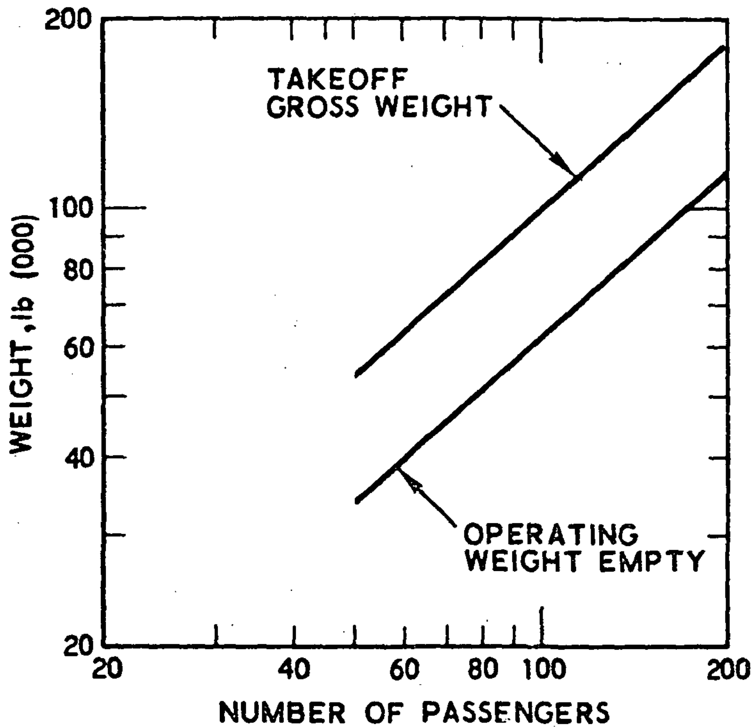


Figure A-3. Design Data

c. Performance

(1) Cruise

The VASCOMP II computer program also produces a set of mission profiles for the Augmentor Wing STOL aircraft, including times from liftoff to touchdown. These profiles were modified to simulate a more realistic flight profile by incorporating the following properties:

- Initial climb speed from takeoff to a 10,000-foot altitude equal to less than half the 250 knots (EAS) used
- Maneuvering after takeoff required to intercept the enroute airway

Table A-1. Aircraft Design Geometry

Passenger Size	50	100	150	200
Fuselage				
Length	70.00	104.80	132.00	159.20
Width	12.40	14.10	14.10	14.10
Wing				
Aspect Ratio	7.00	7.00	7.00	7.00
Area (ft^2)	685.00	1250.00	1784.80	2327.10
Span (ft)	69.20	93.50	111.80	127.60
Mean Aerodynamic Chord (ft)	10.80	14.70	17.50	20.00
Sweep (deg)	25.00	25.00	25.00	25.00
Taper Ratio	0.300	0.300	0.300	0.300
(Thickness/Chord) Root	0.165	0.165	0.165	0.165
(Thickness/Chord) Tip	0.120	0.120	0.120	0.120
Wing Loading (psf)	80.00	80.00	80.00	80.00
Horizontal Stab.				
Aspect Ratio	4.50	4.50	4.50	4.50
Area (ft^2)	181.70	319.80	435.20	533.20
Span (ft)	28.60	37.90	44.30	49.00
Mean Aerodynamic Chord (ft)	6.70	8.90	10.40	11.60
Thickness/Chord	0.120	0.120	0.120	0.120
Length (ft)	45.00	63.00	79.00	96.00
Volume*	1.100	1.100	1.100	1.100
Vertical				
Aspect Ratio	1.20	1.20	1.20	1.20
Area (ft^2)	137.30	247.30	332.50	408.40
Span (ft)	12.80	17.20	20.00	22.10
Mean Aerodynamic Chord (ft)	10.80	14.50	16.80	18.60
Thickness/Chord	0.130	0.130	0.130	0.130
Length (ft)	38.00	52.00	66.00	80.00
Volume*	0.110	0.110	0.110	0.110

*Dimensionless

- Speed on descent through 10,000 feet reduced to 250 knots (EAS)
- Further reduction in speed required in the terminal area to permit intercept of final approach course and to prepare for landing
- Air traffic delays, occasioned by other traffic in the terminal area. A value of 3 minutes was selected, based on dedicated STOL airspace.

The resulting block time accounting for the time needed to taxi-in, taxi-out, roll for takeoff, and landing roll is given by the expression $t_b = 0.269 + 0.0019025R$ where t_b is the block time in hours and R is the straight-line airport-to-airport distance in statute miles. Table A-2 indicates computed block times and associated block fuel for the four baseline aircraft sizes and for five stage lengths.

(2) Terminal Area

Terminal area performance capabilities of the Augmentor Wing STOL aircraft were determined with the aid of a STOL flightpath computer program developed at the Ames Research Center. The program utilizes

Table A-2. Aircraft Block Performance

Stage Length (Statute Miles)	Cruise Altitude (Feet)	50 Passengers		100 Passengers		150 Passengers		200 Passengers	
		Time (Hr)	Fuel (Lb)	Time (Hr)	Fuel (Lb)	Time (Hr)	Fuel (Lb)	Time (Hr)	Fuel (Lb)
50	7,500	0.364	1,928	0.364	3,451	0.364	4,843	0.364	6,244
100	14,000	0.459	2,855	0.459	5,158	0.459	7,119	0.459	9,084
200	26,000	0.650	3,932	0.650	7,085	0.650	9,998	0.650	12,925
300	30,000	0.840	4,737	0.840	8,394	0.840	11,690	0.840	14,9[illegible]
500	30,000	1.220	6,701	1.220	11,825	1.220	16,403	1.220	20,980

aerodynamic (lift/drag) data of the aircraft to examine thrust, flap setting, and speed along paths designated by the user. Aerodynamic properties of Augmentor Wing aircraft were obtained by NASA in wind-tunnel model tests. Aerospace utilized this computer program in determining the approach and departure conditions needed for noise and pollution studies and for examining the advantages of curved approach and departure paths at STOLports with adjacent residential communities. The basic performance limits established from this analysis are summarized in Table A-3.

Table A-3. Augmentor Wing Aircraft Performance Parameters

Segment	Approach	Departure
Power, percent	50	100
Flaps, deg	35	35
Speed, knots	80	80
Path Inclination, deg	7	13.6

A major advantage of powered-lift STOL vehicles is noted in Table A-3; namely, their ability to get into and out of small airports using a minimum of terminal airspace. Fully controlled descents on steep flightpaths using relatively high power settings are feasible, precluding the need for two-segment approaches to provide sufficient margin for a go-around or a normal flare. Steep climb angles are also possible because of the high thrust/weight ratios employed.

Early in the study effort, it was thought that curved approach and departure flightpaths would be helpful as part of a general noise abatement strategy. The basic idea was to avoid flight over residential areas to the maximum extent possible. Thus, the properties of such paths were studied using the NASA-STOL flightpath program. Curved paths were actually applied at a number of California corridor STOLports (Montgomery, Fullerton, Palo Alto, Executive) where details of land uses in the vicinity of the airport suggested their desirability. However, it was ascertained that the combination of low noise, relatively few operations, and steep approach/departure paths restricted the noise-impacted area to the immediate vicinity

of the STOLport, thereby obviating the need for curved paths for noise abatement. This contention is substantiated by results obtained in the study.

(3) Gate Time

Although not considered a traditional part of a mission profile, aircraft gate time influences system economics and derives from design specifications. Gate time (as used in this study) includes the time interval between aircraft arrival and departure from the gate. In general, the time consumed in taxiing to and from the runway does not affect gate requirements and is normally considered part of the aircraft block time. However, the time required for aircraft maneuvering into and out of the gate position is a factor in determining the number of gates required. Other time increments influencing gate time include (a) ramp or stair enplacement and removal, (b) passenger enplaning and deplaning rates, (c) aircraft/cabin servicing rates, (d) the number of passengers, and (e) the number of aircraft doors. Aircraft fueling after engine-stop concurrent with passengers enplaning and deplaning is permissible so long as an attendant is present to ensure that proper fire-hazard safeguards have been provided. To allow time for fueling and baggage handling, a minimum turnaround time with cabin service of 20 minutes, and without cabin service of 10 minutes, was assumed (Ref. 4).

Table A-4 presents the functions influencing gate time and either the fixed time or the rate assumed to conduct these functions, which vary with aircraft size and the number of enplaning/deplaning passengers. The McDonnell Douglas Corporation (Ref. 5) was the primary source of times and rates presented. Turnaround times with and without cabin servicing are illustrated in Figure A-4 as a function of vehicle size.

(4) Extended-Range Operations

Interest in extended-range operations stems from an airline's anticipated need for flexibility in the use of its aircraft. Three candidate

Table A-4. Aircraft Turnaround Time (Two-door Configuration)

Function	Fixed Time or Rate	Example 150-Pax Aircraft Service Required Min.
Shutdown Engines, Emplace Ramps, and Open Doors	1 min	1.00
Deplane Passengers*	40 pass/min	3.75
Service Cabin as Required	12 seats/min	12.75
Enplane Passengers*	20 pass/min	7.50
Close Doors, Remove Ramps, Start Engines	1.5 min	1.50
Passenger Walking Speed (Distance is 25 ft + 1/2 Wing Span)	120 fpm	0.50
TOTAL		27.00

*Aircraft of greater than 150-seat capacity are assumed to have larger doors, which permit rates of: deplaning at 50 pass/min. and enplaning at 25 pass/min.

approaches for facilitating extended-range operations (i.e., operations on routes substantially longer than those in any of the arenas studied and beyond the range capability of the basic 500-statute-mile aircraft) were postulated:

- An aircraft with at least 750 miles design range (adequate, for example, for the New York/Chicago city pair)
- Use of longer landing and takeoff runs (permitting partial-power operation in these flight regimes, which results in fuel savings)
- Reduction of payload on the basic 500-mile aircraft in order to compensate for additional fuel and tankage.

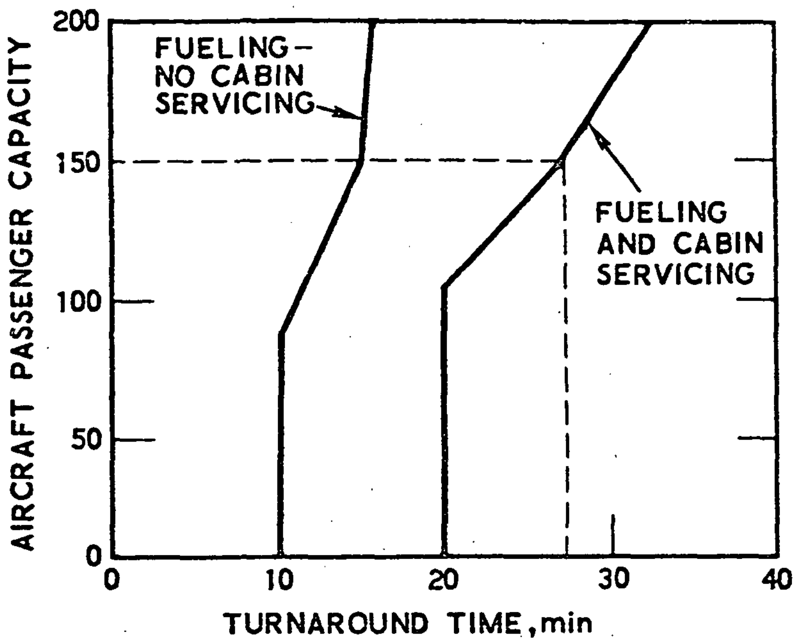


Figure A-4. Turnaround Times

The first approach was discarded because the viability of the larger aircraft would have to be established on the relatively short routes in the three arenas under analysis, contradictory to the original intent of basing the study on a 500-statute-mile aircraft design. The second approach was discarded because some key STOLports in the extended-range arena (e. g., Meigs) could not accommodate partial-power operations on their short runways. Operating the STOL vehicle out of hub airports on the extended-range service, in direct competition with CTOL aircraft, offers no evidence of advantages and has obvious cost penalties. Thus, it was finally decided to restrict the extended-range analysis to one based on an off-loaded version of the basic 500-mile vehicle in which the range extension was sufficient to provide an aircraft for the New York/Chicago market.

The passenger/fuel tradeoff was made on the basis of the following assumptions:

- Takeoff gross weight remains unchanged
- One passenger and his baggage is equivalent to 220 pounds of payload
- Fuel system weight increases in proportion to fuel weight requirements
- Fuel system sizing is based upon 1150-statute-mile range
- Rate of fuel consumption during cruise is unchanged from that of the basic aircraft
- Additional fuel is carried within volume and balance limits of basic aircraft
- Fuel reserves are equal to those of basic vehicle
- Allowance is made for food service equipment due to extended flight time.

Aircraft parameters used in the New York/Chicago city-pair analysis are indicated in Table A-5, while Figure A-5 shows the effects of range

Table A-5. Extended-Range Augmentor Wing Parameters

No. of Passengers (Basic Aircraft)	50	100	150	200
Takeoff Gross Weight (lb)	54,801	100,000	142,782	186,169
Adjusted Operating Weight Empty (lb)*	34,970	62,400	87,946	114,206
Adjusted Passenger Capacity (750-S.M. trip)**	33	72	110	148
Available Seats (Percent of Basic Aircraft)	66	72	73.3	74
Equivalent Maximum Average Load Factor***	0.429	0.468	0.476	0.481

*Additional tankage weight based on 1150-SM capability. Excludes food service weight.

**Includes seat loss to provide food service.

***Based on maximum average load factor equal to 0.65 of available seats.

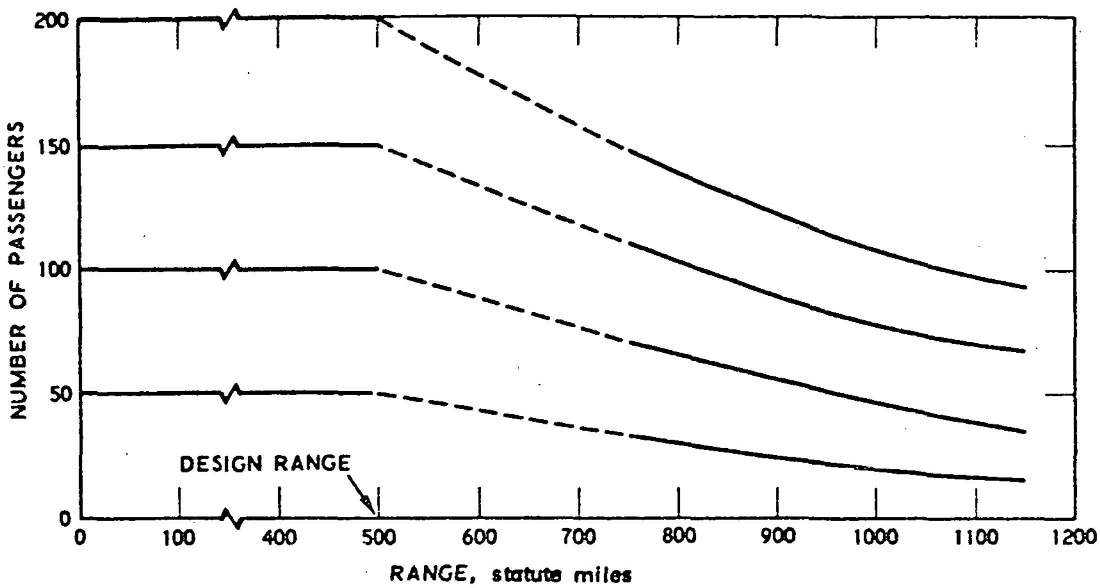


Figure A-5. Extended-Range Aircraft Passenger Capacity

extension on the maximum number of passengers that can be carried. The dashed lines in this plot branch the transition from the basic aircraft with no food service allowance to the extended-range concept; they do not represent performance estimates.

The basic economic inputs for the extended-range mission were the same as those utilized for the Northeast Corridor (NEC) arena, except for utilization, food service, and port-related IOC (ΔIOC). The New York/ Chicago extended-range mission involves two time zones and would operate from ports with an operating day restricted from 7:00 a.m. to 10:00 p.m. These two factors produce scheduling limitations estimated to reduce the potential annual hours of aircraft utilization by 15 percent, relative to those of the NEC STOL system. The average turnaround time was changed to include cabin cleaning after each one-way trip. As a consequence, the 150-passenger STOL had its turnaround time increased from 0.343 to 0.45 hour. Indirect operating costs were increased by $2.00 per passenger for meal

service. This was based on an average of $4.00 per meal and meal service being offered on 50 percent of the flights. The port-related IOC for the extended-range mission was derived by taking the average of those obtained for the Midwest Triangle and Northeast Corridor on the basic short-haul service.

d. Noise

A key element affecting the acceptability of short-haul air service from "neighborhood" airports is the issue of noise. The "noisiness" of any particular aircraft, the level of operations, and the land use patterns adjacent to the airport all contribute to the question of a community's acceptance of aircraft operations. Noise buffer zones around an airport are one method of diminishing community objections. Considerations entering into the creation of buffer zones are discussed later in this section; the methods for enfolding their costs into an analysis of any new short-haul aircraft system are described in Section A.3. The purposes of the current subsection are to discuss the aircraft noise phenomena, describe the noise characteristics of the Augmentor Wing STOL aircraft used in this study, and explain the preparation of noise data and their use in quantifying the impact upon people on the ground.

(1) Sources of Engine Noise

Noise from jet engines used on most existing and all proposed subsonic airline jet aircraft emanates from the engine inlet, the annular fan-discharge duct, and the hot core-jet exhaust. The annoying siren-like whistle associated with this type of engine is a function of blade passage frequency, which in turn is related to fan speed and the number of fan rotor and stator blades. Whether the fan tip speed is subsonic or supersonic also has a major effect on the character of the noise. Engine spectra indicate that strong peaks at mid-frequency in the audible range occur at approach power

and reach the observer mainly through the inlet. So-called turbomachinery noise, probably the least well-understood noise source in a turbine engine, emanates from the fan duct. The very loud low-frequency roar of the core jet is produced by the turbulent mixing of high-speed exhaust gases with relatively cold outside air.

In the Augmentor Wing powered-lift concept, the annular fan-exhaust duct is replaced by a manifold in the aircraft's wing, as in Figure A-6. Fan air is led to this manifold and from there through a series of nozzles and finally out through the augmentor flap system. In order for this design to produce the extremely high lift augmentation required to achieve a 2000-foot FAR field-length, hot day capability, a very high-capacity, high-pressure-ratio fan is needed. The resulting multistage supersonic-tip speed fan is extremely noisy, requiring new and radical approaches toward achieving noise reductions needed to reach the goal of 95 EPNdB at a 500-foot sideline distance from the aircraft. The difficult noise problem is further compounded by a new source of noise, that of the augmentor system, which adds to the turbomachinery noise ordinarily emanating from the fan discharge. A significant reduction in jet noise is possible, however, in the augmentor type of engine. The design lends itself to the use of subsonic jet-exhaust velocities, thus materially reducing turbulent mixing noise.

From the standpoint of ground noise, the critical flight regimes are approach, landing roll, takeoff roll, and departure. For the Augmentor Wing STOL, these flight regimes are normally characterized by power levels between 50 and 100 percent and flap settings between 20 and 65 degrees. It was, therefore, necessary to characterize the aircraft's noise throughout this range of parameters [illegible]tunately, much of the basic data needed to develop effective perceiv[illegible]evel (EPNL) versus slant-range matrices were available, through NA[illegible]m several key STOL study contractors. Specifically, Boeing conducted a detailed experimental and design study of the Augmentor Wing concept for the Ames Research Center (Ref. 2). Boeing's experimental studies provided much of the augmentor system noise data used in this study.

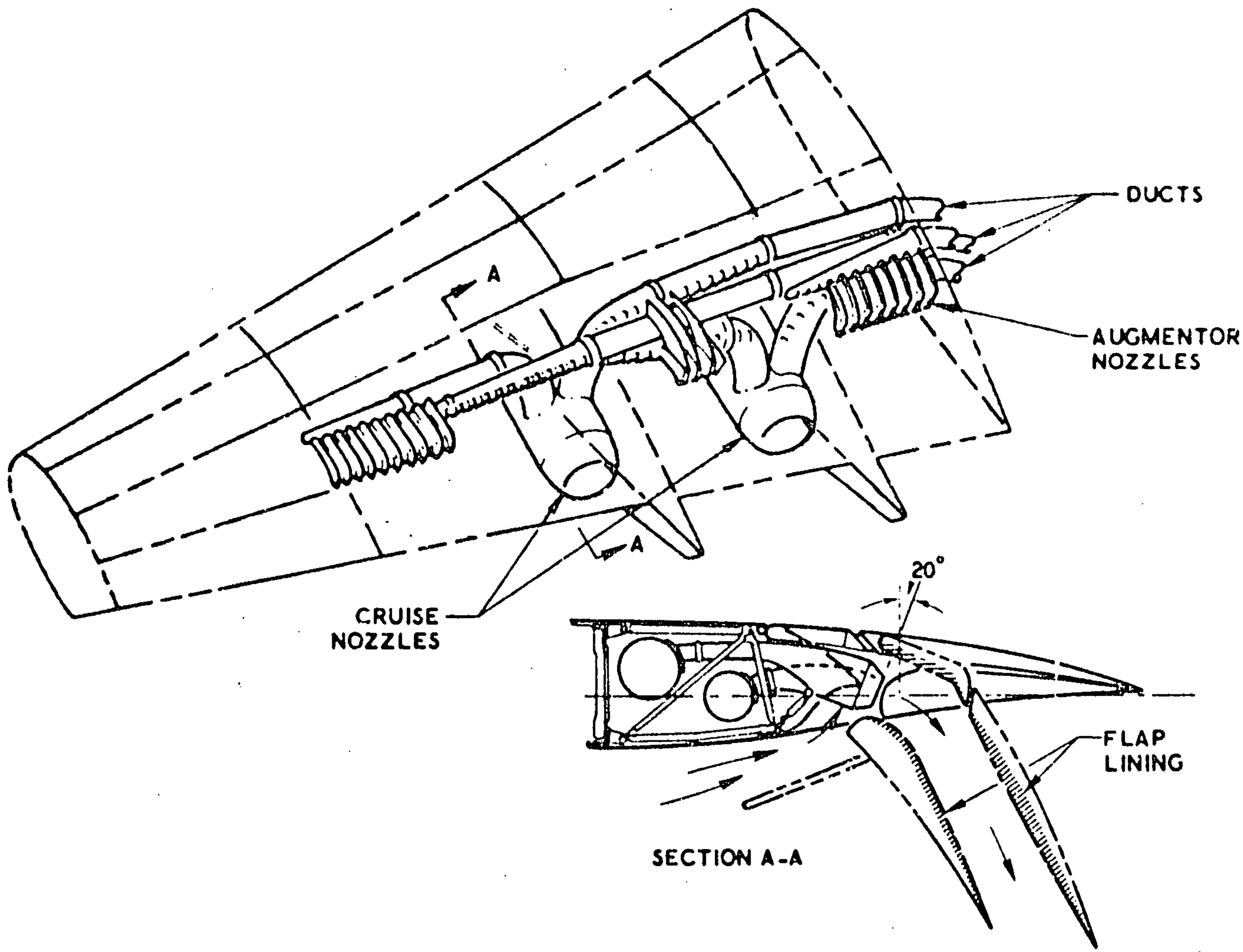


Figure A-6. Augmentor Duct, Nozzle, Flap, and Structure Integration (Ref. 1)

The Boeing design studies, however, were based on the Pratt and Whitney STF 395D (BM-1) two-stream engine concept. NASA directed that Aerospace consider aircraft concepts that were similar to Boeing's designs but modified through use of the Detroit Diesel Allison PD 287-43 two-stream engine concept (Ref. 5). Table A-6 provides a comparison between the two engines. Both have very high fan-pressure ratios and tip speeds, low (by comparison with today's engines) exhaust-gas velocities, and very high thrust splits (ratio of cold to hot thrust). From the noise point of view, there are two important differences between these engines:

- The higher Allison thrust split increases the inlet and augmentor noise. This effect is offset by the fact that the higher augmentation ratio possible with the Allison engine reduces the total thrust required to produce a satisfactory aircraft design. For example, NASA indicates a requirement for 15,300 pounds of thrust per engine for the 150-passenger aircraft versus 18,640 pounds of thrust per engine for the comparable Boeing design. This, in turn, results in an aircraft of significantly lower takeoff gross weight (TOGW) than indicated by Boeing for similar passenger capacities.
- The lower core-engine-exhaust velocity of the Allison engine further reduces jet noise levels and simplifies the problem of jet noise control.

(2) Augmentor Wing Noise Source Data

Information has been acquired and analyzed on inlet, core jet, and augmentor system noise. These three sources are separately analyzed in

Table A-6. Augmentor Wing Aircraft Engine Comparison

Engine Type	Fan Pressure Ratio	Bypass Ratio	Total Pressure Ratio	Fan Stages	Fan Tip Speed ft/sec	Primary Nozzle Velocity(ft/sec) at 100 knots, std day	Approximate Thrust Split
Allison PD 287-43	3.00	2.80	20.0	3	1530	700	86/14
Pratt & Whitney STF-395D(BM-1)	3.20	2.07	25.6	3	1454	779	80/20

the following paragraphs, then appropriately combined to determine the noise characteristics of the Augmentor Wing aircraft.

(a) Inlet

The engine described in Table A-6 uses a three-stage fan with supersonic tip speed. This configuration produces a high intensity "buzz-saw" noise (also known as multiple pure-tone noise) created by the interaction with incoming airflow of shock waves formed on the leading edge of the fan blades. This phenomenon is shown diagramatically in Figure A-7. The resulting noise levels require a radical new approach to achieve adequate

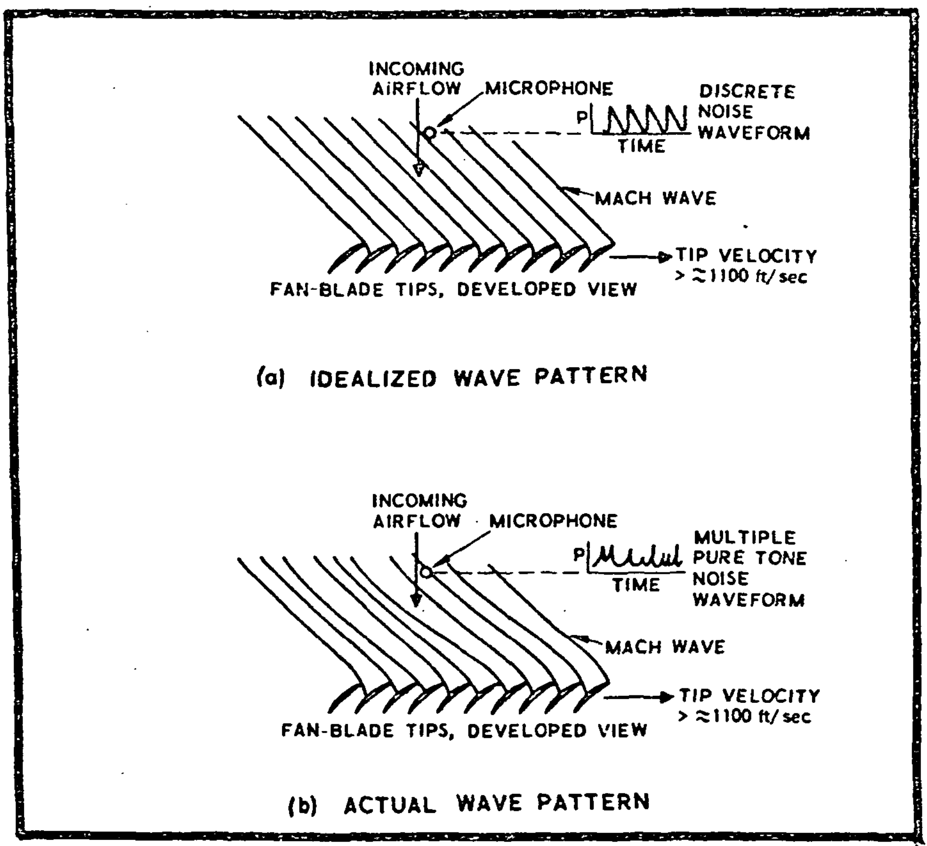


Figure A-7. Multiple Pure Tone Noise from Supersonic Tip Speed Fans (Ref. 7)

suppression. NASA has suggested the use of a sonic inlet (Ref. 8), which Aerospace has assumed will be available for use with the Augmentor Wing aircraft. In this concept, the incoming air is at or near sonic velocity, so that acoustic waves cannot propagate forward and emanate from the engine inlet. The basic idea of inlet choking is illustrated in Figure A-8 along with several potential inlet configurations. The performance of the sonic inlet as a function of Mach number is shown in Figure A-9 (Ref. 9). The almost spectacular noise reductions indicated must still be corroborated by further testing, but the basic concept of the inlet appears sound.

Multiple-stage fans are shown in Figure A-10 to vary in acoustic output as a function of fan-pressure ratio (FPR) (Refs. 8 and 9). These data are for the unsuppressed case, but, if it is assumed that the effectiveness of the sonic inlet concept is constant in the pressure ratio range of Figure A-10, then inlet noise will scale as shown. Boeing and Allison both quote inlet noise as 92 PNdB at a 500-foot sideline for a fully suppressed sonic inlet on an engine of 15,000 to 18,000-pound thrust. To find the noise levels at part-power conditions, it was assumed that FPR decreases in proportion to the

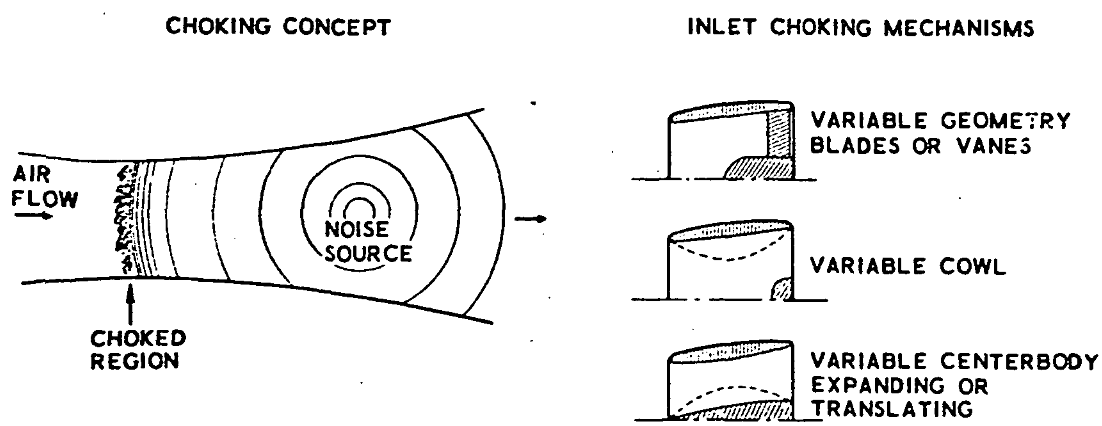


Figure A-8. Sonic Inlet (Choking) Concept
(Ref. 8)

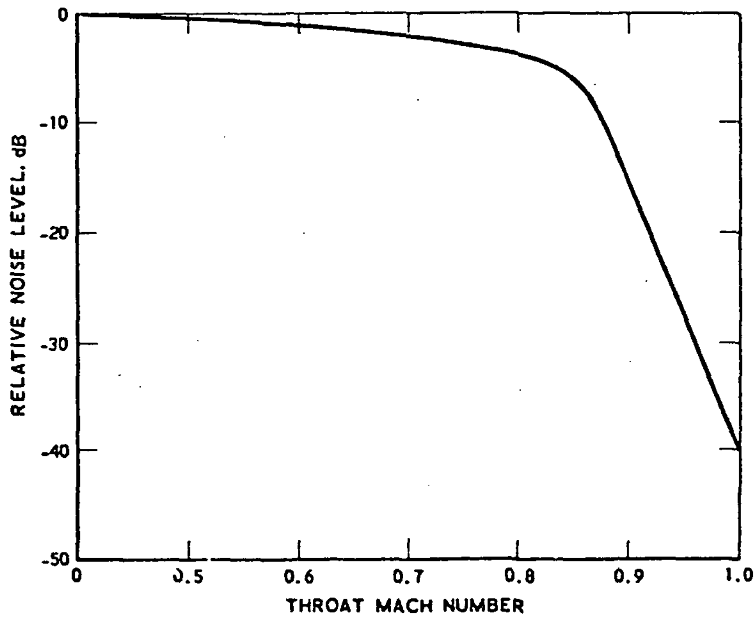


Figure A-9. Sonic Inlet Performance

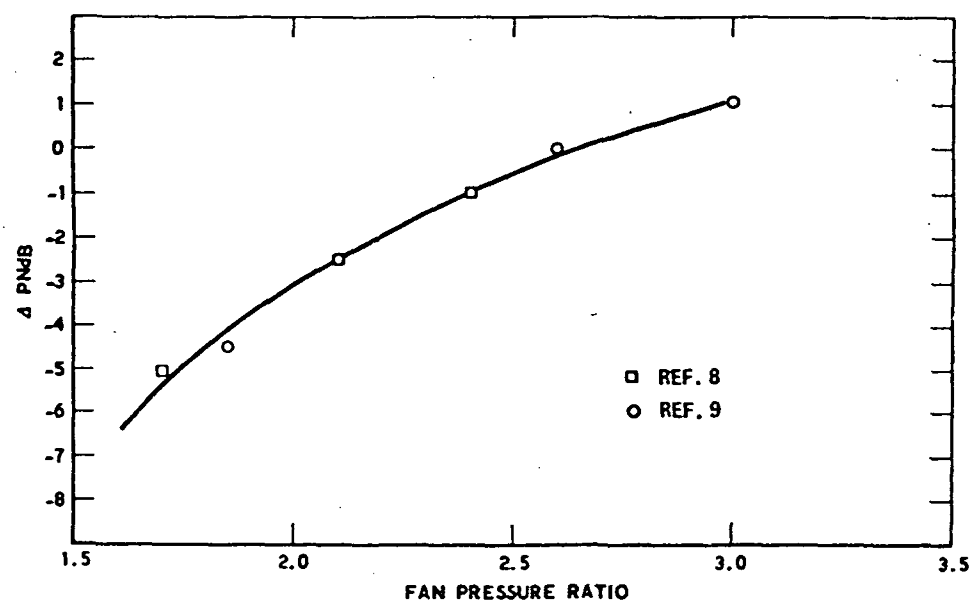


Figure A-10. Fan Approach Noise, Unsuppressed

augmentor-nozzle pressure ratio at corresponding thrust levels. This assumption is conservative, since duct losses from the fan discharge to the augmentor are dependent on some power of velocity greater than 1. For example, at 75-percent thrust, the estimated FPR will be high and result in a noise estimate which may be 1 to 2 PNdB high. At 50-percent thrust, the noise estimate may be as much as 2 to 3 PNdB high. The noise levels arrived at using this approach and the data of Figure A-10 are shown in Table A-7. It will be shown later that inlet noise is not the predominant noise source at any thrust setting, so that the extra degree of conservatism does not unduly bias the final noise estimate.

Table A-7. Inlet Noise, 500-foot Sideline

Thrust, Percent	50	75	100
Fan Pressure Ratio	2.0	2.5	3.0
Inlet Noise Level, PNdB	88	90.5	92

(b) Core Jet

The core engine exhaust of the Allison PD 287-43 produces 93 PNdB at a 500-foot sideline distance for a 150-passenger aircraft at 100 percent thrust, and 83 PNdB at 50 percent thrust (Ref. 6). In order to estimate the perceived noise level corresponding to 75 percent thrust, one must determine core-jet velocity at this thrust level relative to that at 50 percent and 100 percent thrust. The Boeing extension of the Society of Automotive Engineers (SAE) jet noise curve (Ref. 10) shown in Figure A-11 may then be used to provide a conservative noise estimate.

Allison indicates a core exhaust velocity of 700 ft/sec at 100 percent thrust of the PD 287-43 engine, but no corresponding data are provided for 50-percent thrust. Data on the Pratt and Whitney STF-344 shown in Figure A-12 were therefore used to develop a core-velocity/thrust correlation. It may be observed that 50-percent thrust occurs at 61 percent of maximum core velocity, while 75-percent thrust occurs at 82 percent of maximum

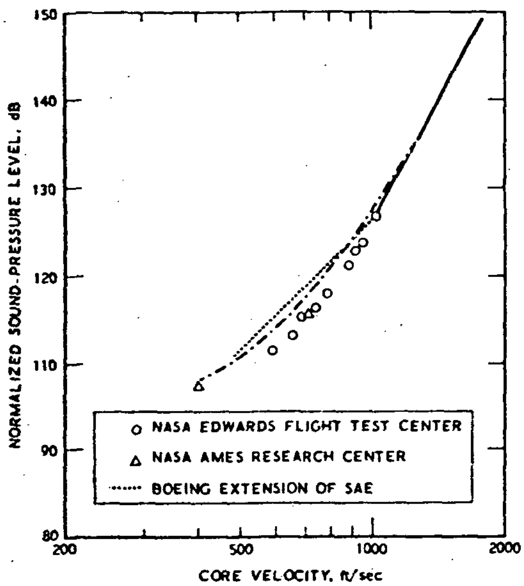


Figure A-11. Jet Noise Comparison

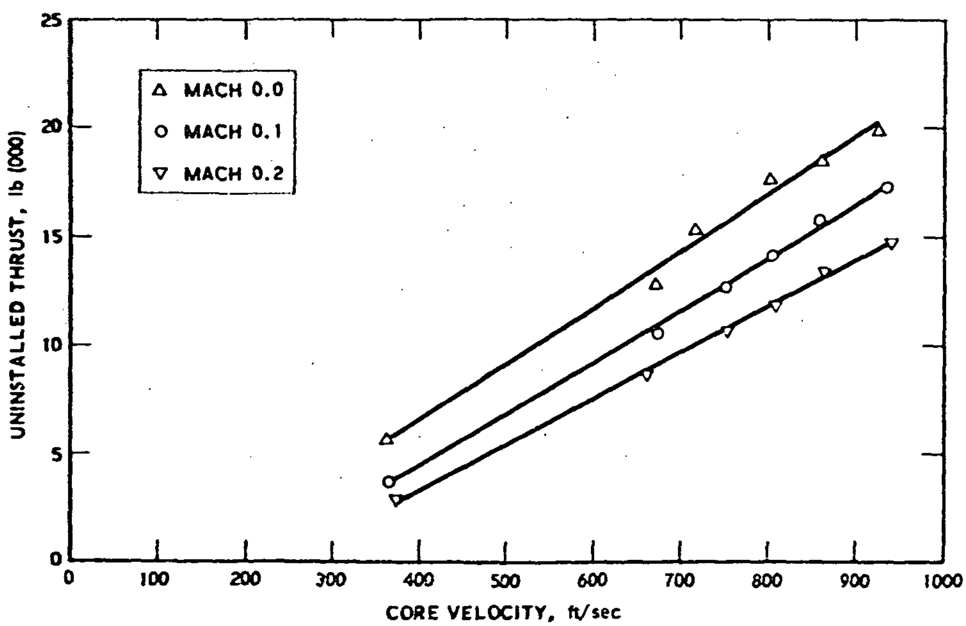


Figure A-12. STF-344 Sea-Level Data

velocity. The latter corresponds to 574 ft/sec in the Allison engine. Using this velocity in Figure A-11, a reduction of 4 dB is obtained when power is reduced from 100 to 75 percent. The data illustrated in Figure A-11 also indicate an approximate 10-dB noise reduction at 61 percent of the Allison engine maximum core velocity, corresponding to Allison's indicated reduction.

Perceived noise levels (PNLs) at the 500-foot sideline are listed in Table A-8 for the core engine exhaust only.

Table A-8. Core Jet Noise, 500-foot Sideline

Thrust, Percent	50	75	100
Core Jet Noise, PNdB	83	89	93

(c) Augmentor System

The principal direction of Boeing's work for NASA has been toward development of an efficient and quiet lift-augmentation system. Figure A-13(a) indicates a number of the configurations tested by Boeing, while Figure A-13(b) notes the gradual reduction in the peaks of Noy-weighted spectra with improvements in nozzle design. Boeing's recommended design, shown previously in Figure A-6, includes an array of lobed nozzles to which are attached screech shields. The shields move the peak of the noise spectrum to a frequency that is more easily attenuated by the tuned acoustic linings on the inner surfaces of the augmentor flap. A lower air-gap baffle is also added to the flap system to further reduce noise levels.

The upper curve in Figure A-14 indicates the perceived noise levels computed by Boeing for the tested augmentor system. Boeing has estimated that this system may be substantially improved in the near term, resulting in the lower curve of Figure A-14. To compute augmentor system noise levels for use in community noise analyses, it was decided to characterize augmentor noise by means of a curve located between the two Boeing curves. Augmentor nozzle pressure ratios were found by Boeing to vary linearly with

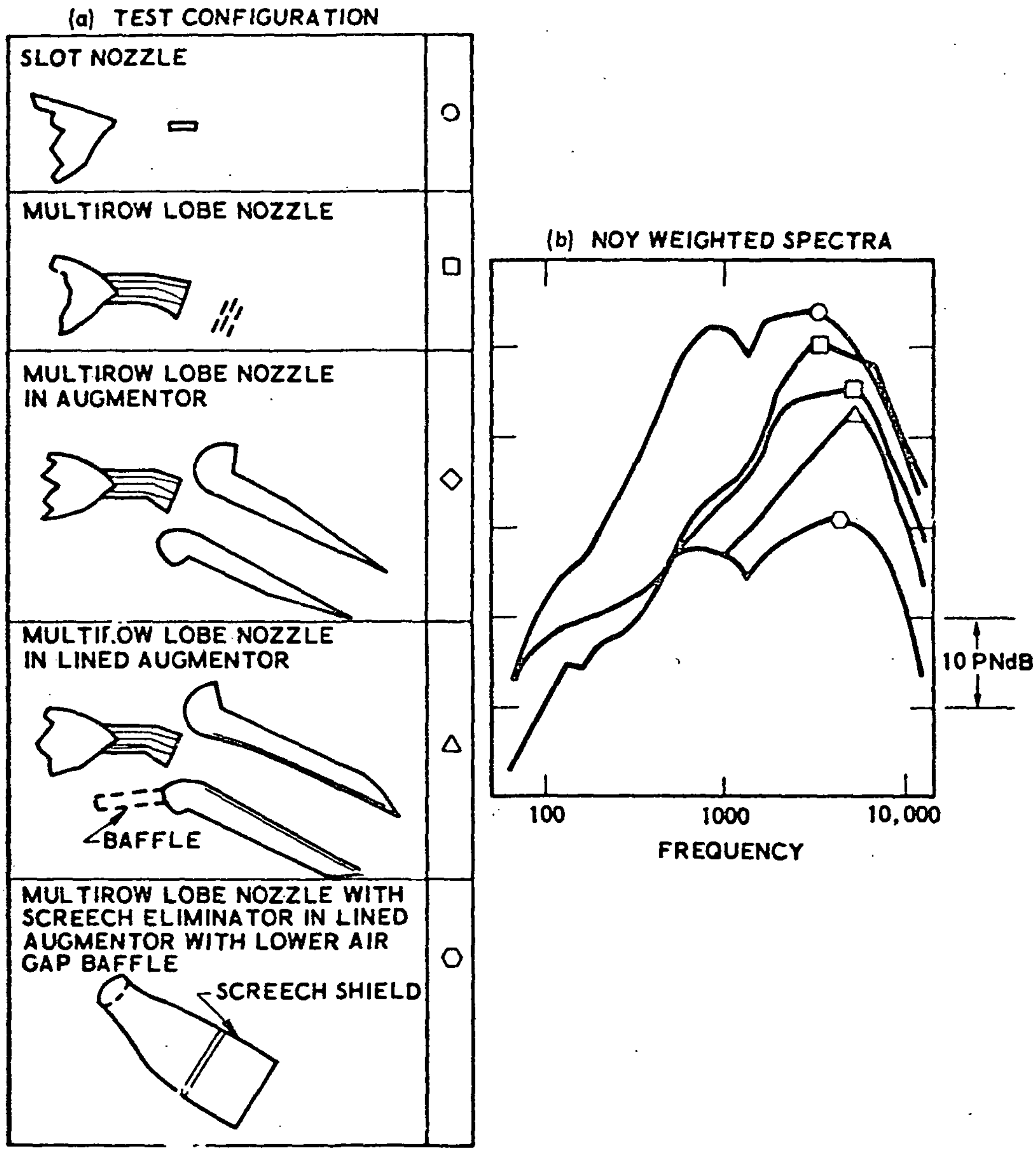


Figure A-13. Augmentor Noise Reduction Development (Ref. 2)

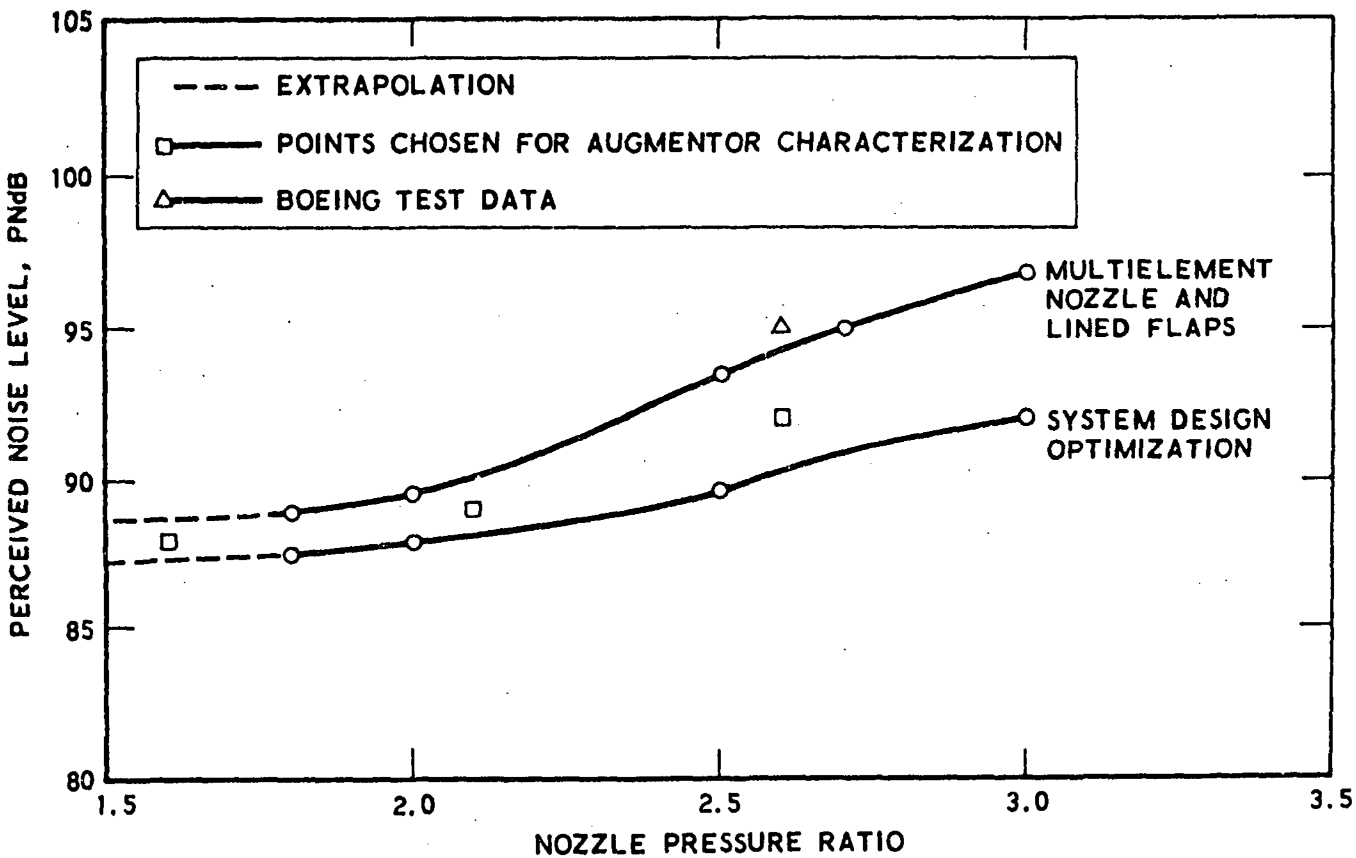


Figure A-14. Augmentor Noise Contribution, 35° Flap

thrust in the region from 50- to 100-percent power, so that it was possible to determine the required perceived noise levels directly from the figure. The results are shown in Table A-9 for the 35-degree flap case.

Table A-9. Augmentor System Noise, 500-foot Sideline
35-Degree Flap

Thrust, Percent	50	75	100
Nozzle Pressure Ratio	1.6	2.1	2.6
Augmentor Noise Level, PNdB	88	89	92

To find the effect of flap setting on augmentor system noise levels, one may note in Figure A-6 that the augmentor nozzles are permanently set at an angle of 20 degrees to the wing's horizontal center line; the flap moves in relation to these nozzles. Boeing has found that, for flap angles between 0 and 35 degrees, flow will proceed through the double-flap assembly with minimal direct impingement of high-velocity air onto flap inner surfaces. Thus, the absorptive lining efficiency remains relatively constant over this range of flap settings, and the data in Table A-9 are applicable. At 65 degrees of flap, impingement of airflow from the nozzles onto the flap's inner surfaces does occur. The polar plot of Figure A-15 indicates that this effect shifts the peak of the perceived noise level curves. Figure A-16, plotted in terms of test-model frequency (full-scale frequency is equal to test-model frequency divided by 6.4) indicates that noise levels at higher frequencies are slightly attenuated at the higher flap setting. This effect is probably due to turbulence near the flap wall, whose associated noise is effectively attenuated by the tuned acoustic linings. In addition, the efflux from the flap assemblies will be at a slightly reduced velocity after impingement, so that noise due to turbulent mixing at the flap exit is also reduced. As a consequence, the noise levels at the 65-degree flap setting were established at 1-dB below those at the 35-degree setting.

The acoustic performance of the augmentor system as developed by Boeing is summarized in Figure A-17. The polar plot (Figure A-17a)

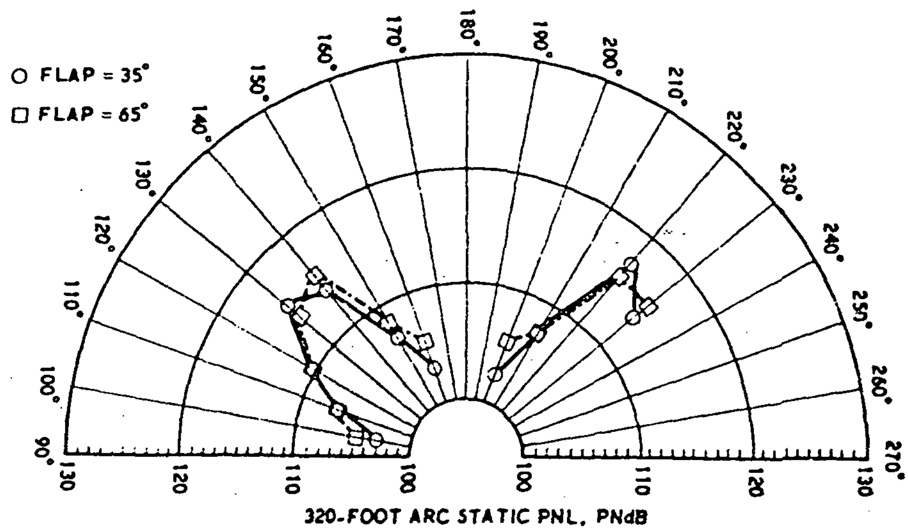


Figure A-15. Effect of Flow Turning on PNL Beam Pattern*

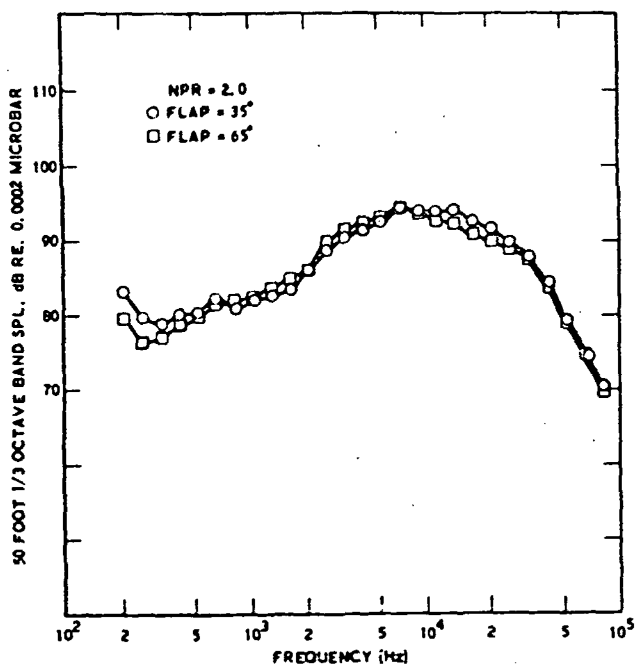


Figure A-16. Effect of Flow Turning on Spectral Noise Content*

* Ref. 2

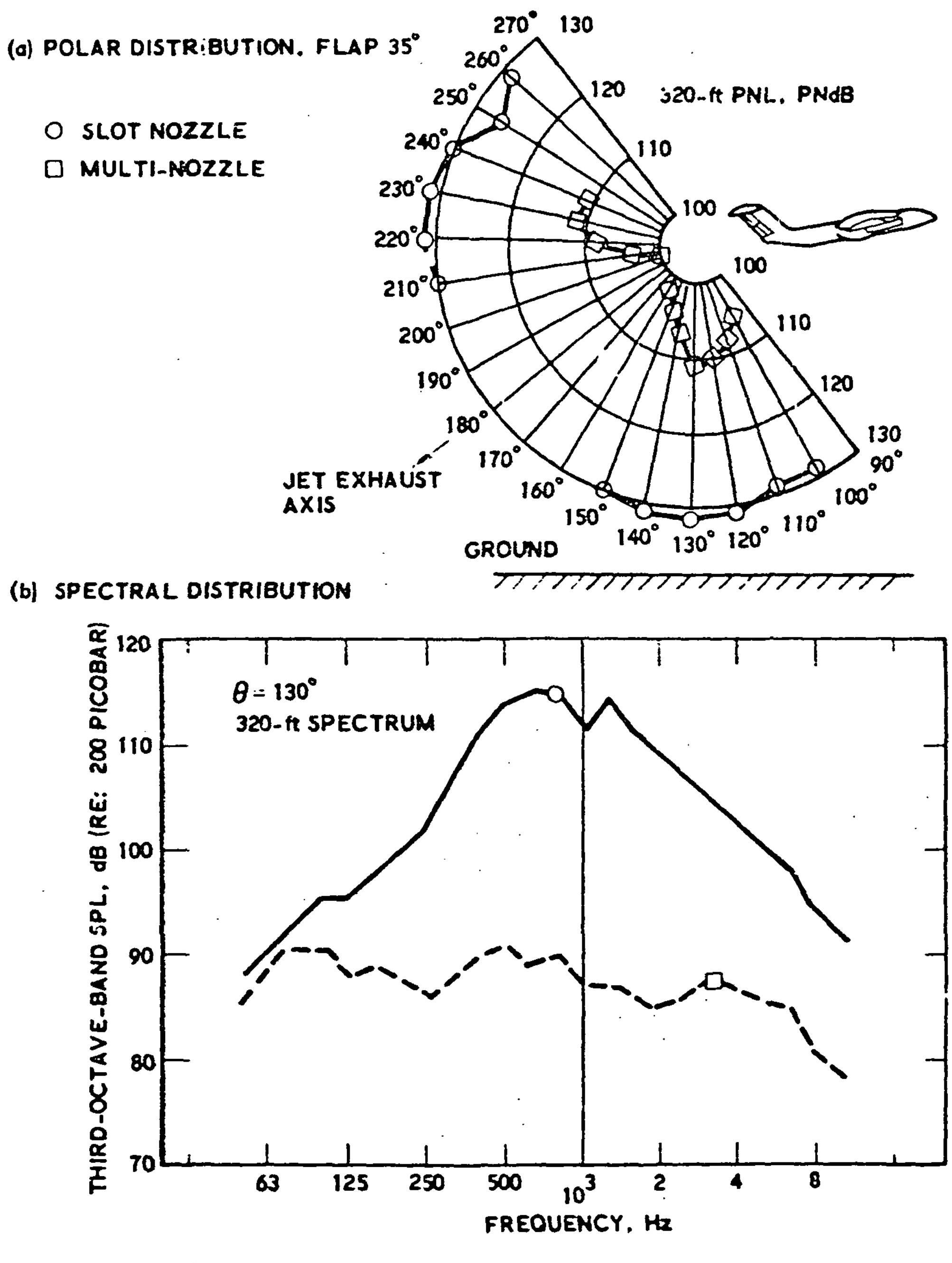


Figure A-17. Augmentor System Noise Performance, 150-Passenger Aircraft (Ref. 2)

compares the noise situation with a slot nozzle versus that with the Boeing lobed-nozzle array, indicating a 21-PNdB reduction in the peak noise at takeoff power conditions; spectral distribution plot, Figure A-17(b), indicates the flatness of the noise spectrum emanating from the augmentor system and an almost 25-dB reduction in the peak sound-pressure level.

(d) Combination of Noise Sources

For reference, the various noise source contributions at the 500-foot sideline distance are indicated in Table A-10. These data must now be combined to produce the total noise received at the observer's station. This was done by combining the core jet noise and augmentor noise, using the conservative assumption that they are additive. Boeing contends that the three sources (augmentor, engine inlet, and core exhaust) are independent because of their highly directional natures. It seems conceivable, however, that the lower lobe of the core-engine exhaust noise and upper lobe of the augmentor noise could combine under certain conditions to create a noise level on the ground greater than any single source. Since the goal of the analysis was to establish EPNLs, only the peak value occurring during a flyover was considered. Therefore, the sum of the augmentor and core-engine exhaust noise was compared to the inlet noise to see which was greater, and in all cases the aft radiating noise source predominated.

Table A-10. Noise Source Contributions 500-foot Sideline

Thrust, Percent	50	75	100
Inlet Noise, PNdB	88	90.5	92
Core Jet Noise, PNdB	83	89	93
Augmentor Noise, 20-deg to 35-deg Flap, PNdB	88	89	92
Augmentor Noise, 65 deg Flap, PNdB	87	88	91

Shift to a 500-foot slant range from a 500-foot sideline had to be accomplished before considering propagation phenomena. This was done assuming that the 500-foot sideline is equivalent to a 550-foot altitude (Ref. 2). This relationship is the result of including excess ground attenuation in the sideline noise results. Applying simple spherical divergence to PNL at a 500-foot sideline results in an increase of 0.6 PNdB. Since only a 50-foot change was being considered, no atmospheric attenuation was involved. The resultant levels of PNL at a 500-foot slant range for a baseline 150-passenger Augmentor Wing STOL aircraft are provided in Table A-11.

It may be noted in Figures A-15 and A-17 that powered-lift aircraft such as the Augmentor Wing STOL may be expected to beam their noise in preferred directions, thereby resulting in significant spatial effects, which must be accounted for. Test data (Ref. 2) have shown that reductions of 2.7 dB in perceived noise level may be expected when observing the aircraft "along the wing." This effect is shown in Table A-12 and has been included in the noise analysis computer program used in this study.

Table A-11. Perceived Noise Level, 500-foot Slant Range, 150-Passenger Augmentor Wing Aircraft

Flap \ Thrust	50 Percent	75 Percent	100 Percent
20 deg to 35 deg	89.8	92.6	96.1
65 deg	89.1	92.1	95.6

Table A-12. Spatial Variation of Augmentor Wing Noise

Angle Between Observer and Aircraft Vertical Plane (Degrees)	Noise Reduction PNdB
0	0
30	0.3
60	1.2
90	2.7

(3) Noise Propagation

The results presented in Table A-11 form the basis for developing the required effective perceived noise level versus slant range data for the STOL aircraft sizes of interest (50 to 200 passengers), the range of power levels expected (50 to 100 percent thrust), and the flap settings required on landing and takeoff (20° to 35°, and 65°). The EPNL is derived from PNL by accounting for the effects of strong tones (assumed to be nonexistent in the highly noise-controlled Augmentor Wing concepts being considered) and for overflight duration. Starting from the reference location of 500-foot slant range, effects of atmospheric absorption and spherical divergence are applied to the derived EPNL values to arrive at noise levels at other slant ranges.

Atmospheric absorption must be considered in relation to the Noy-weighted spectrum. The Noy is a unit used in the calculation of perceived noise level (PNL), which weights a noise spectrum based on subjective ratings for annoyance as a function of frequency and amplitude. Thus the actual spectrum is adjusted by these factors to determine the frequency at the weighted peak and the absorption determined at this frequency. In this manner, PNL can be propagated instead of carrying the entire spectrum representation through all the calculations and finally converting to PNL at the end of the computations. The augmentor spectrum is the dominant one, since it is somewhat biased toward the higher frequencies with respect to the core-jet spectrum. The inlet was not considered in this analysis since, as shown earlier, it is less noisy than the combined augmentor core-jet.

The spectrum chosen for making absorption computations is the lowest one in Figure A-13(b). It is associated with an augmentor design consisting of multiple nozzles with screech shields, lined augmentor flaps, and lower air-gap baffle. This Noy-weighted spectrum is reproduced in Figure A-18 and indicated as occurring at a 500-foot slant range. Note that its peak is at 4000 Hz. To find the spectra at greater distances from the aircraft, the spectral absorption data shown in Figure A-19 are used (Ref. 10). The

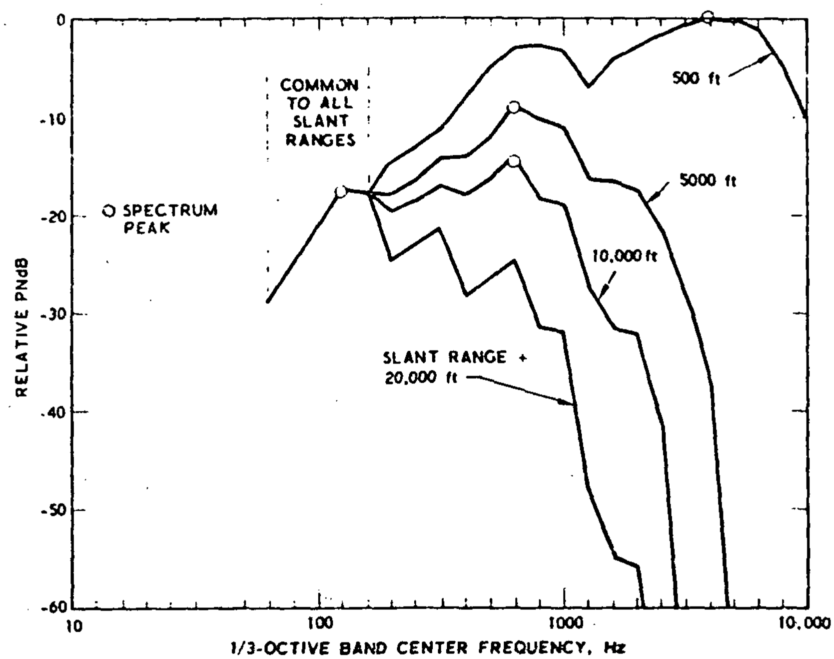


Figure A-18. Atmospheric Effects on Propagation of N /-Weighted Spectra

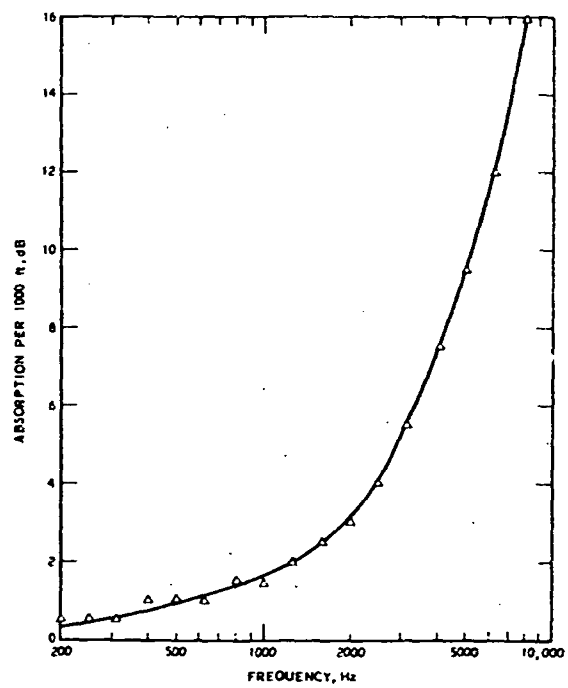


Figure A-19. Atmospheric Absorption per 1000 feet, Standard Day

results, shown in Figure A-18, indicate a significant movement of the spectrum peak to lower frequencies. The absorption correction (in PNdB per 1000 feet of slant range) associated with these peaks is shown in Figure A-20.

The duration correction is based on the premise that the degree of annoyance associated with an overflight is related to the time when an observer experiences noise levels within 10 dB of the peak level. An empirical correction of PNL has been postulated (Ref. 11) to account for this effect. When the duration of noise within 10 dB of the peak is 15 seconds, the correction is zero. Longer durations produce a positive correction, and shorter durations produce a negative correction. The empirical expression is:

$$\text{Duration correction (in dB)} = 10 \log_{10} \left(\frac{\text{duration (seconds) within 10 dB of peak}}{\text{15 seconds}} \right)$$

To find the overflight times associated with Augmentor Wing STOL aircraft, it was necessary to utilize data from overflights of 2-, 3-, and 4-engine turbofan aircraft (Ref. 12). These CTOL aircraft fly at speeds

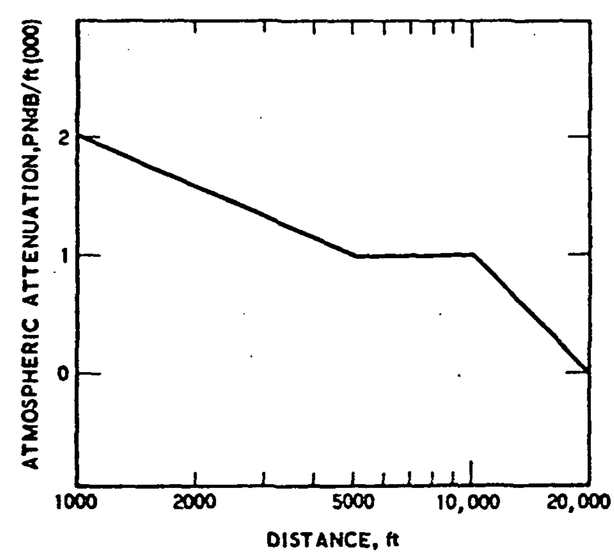


Figure A-20. Atmospheric Attenuation of Noy-Weighted Spectrum

approximately 50 percent above those of STOL aircraft near final approach and just after takeoff. Thus, the curve shown in Figure A-21 has been appropriately scaled upward from CTOL data. As a check on this approach, data describing Boeing CTOL duration corrections were obtained, increased by 1 dB to account for the difference between CTOL and STOL overflight times, and compared to the results whose duration corrections were computed using the times illustrated in Figure A-21. The resulting close correspondence is shown in Figure A-22.

With the atmospheric and duration corrections just described, the shape of the EPNL versus slant-range curve may be defined. Starting with

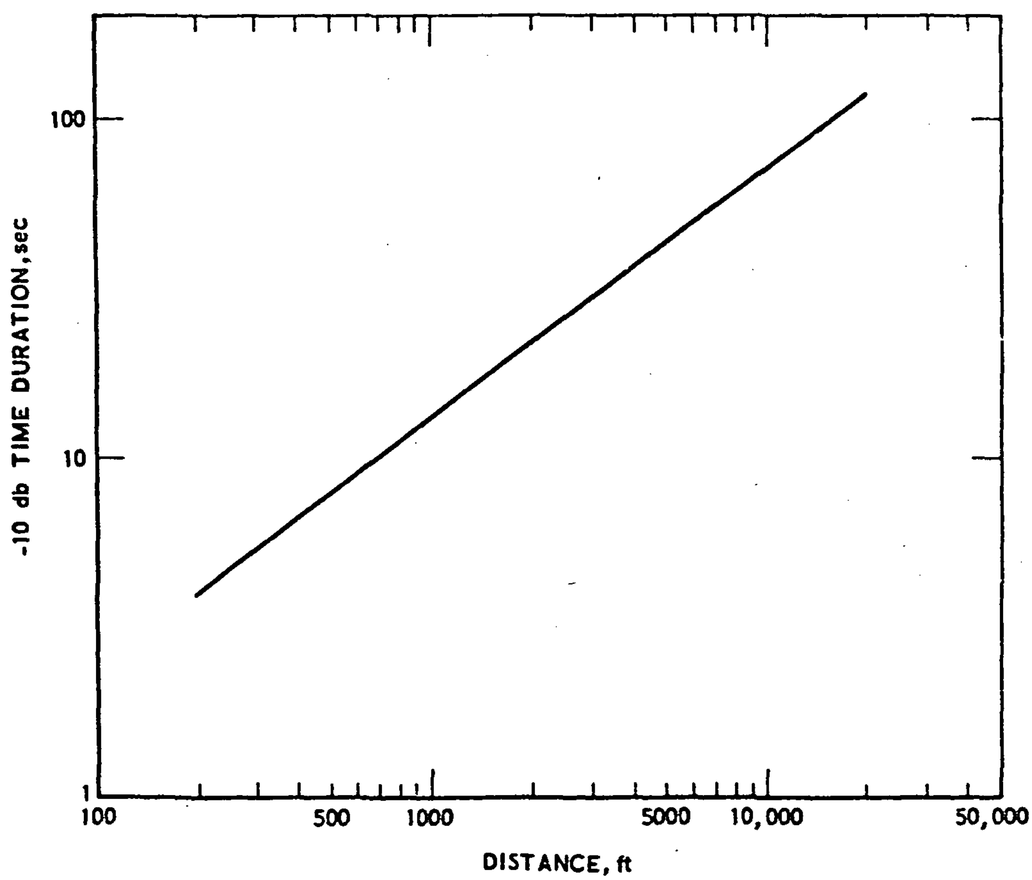


Figure A-21. Duration Corrections versus Distance

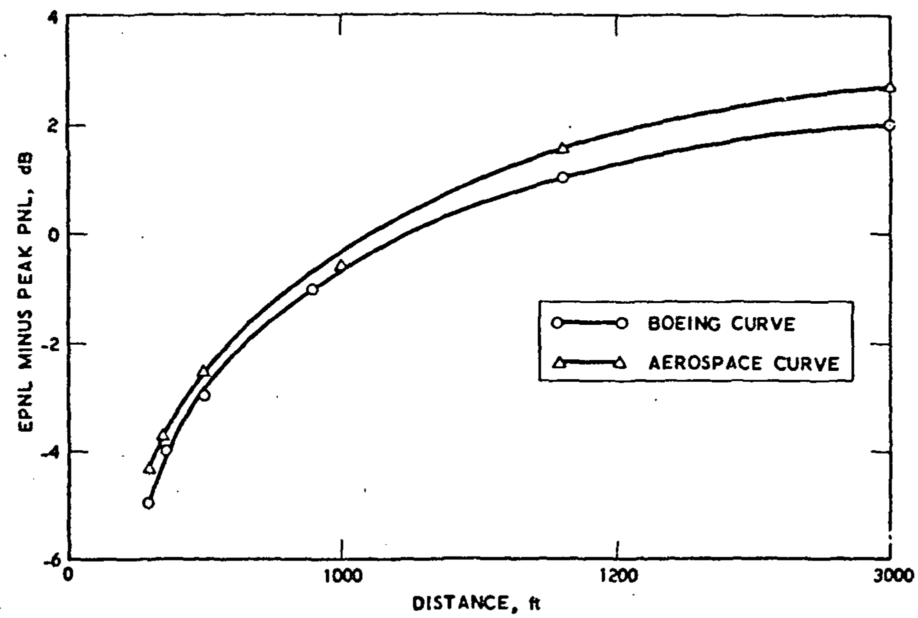


Figure A-22. Transfer Function Relating EPNL to Peak PNL

0 PNdB as a reference level at a 500-foot slant range, the spherical-divergence curve may be drawn by changing the level 6 dB per doubling (or halving) of distance, as indicated by curve 1 in Figure A-23. Subtracting the atmospheric corrections shown in Figure A-20 (noting that there is zero correction at 500 feet and below) yields curve 2 in Figure A-23. Adding the duration correction computed for the times in Figure A-21 to curve 2 of Figure A-23 yields curve 3, the final EPNL shape. Applying this curve shape to the data of Table A-12 finally yields the EPNL versus slant-range curves of Figure A-24, for the 150-passenger Augmentor Wing STOL with flaps set in the 20° to 35° range.

In finding the noise curves for other aircraft sizes, it was assumed that the basic curve shape remains the same but that the noise levels vary as a function of engine thrust in accordance with the relationship:

$$\Delta \text{EPNL (in dB)} = 10 \log_{10} \left(\frac{\text{Thrust}}{\text{Thrust}_{\text{Ref}}} \right)$$

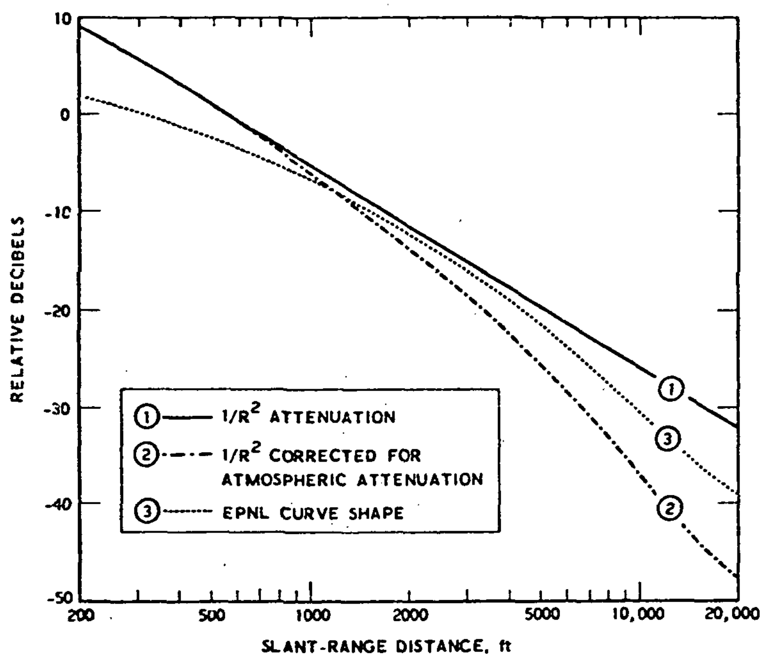


Figure A-23. Conversion of PNL at 500 feet to EPNL vs Slant Range

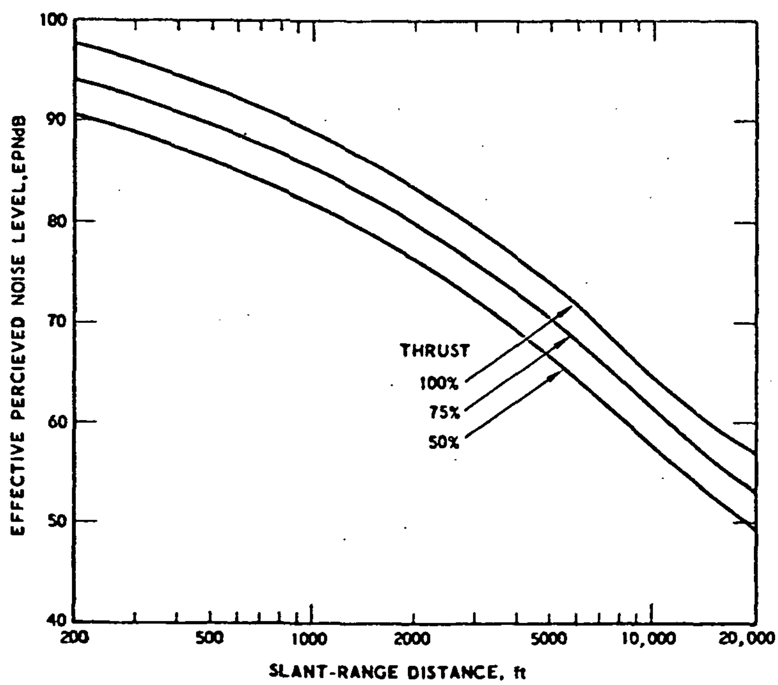


Figure A-24. Augmentor Wing Aircraft Noise, 20° to 35° of Flap

e. Air Pollution

The study of aircraft exhaust emissions compared two turbofan engines projected for installation in CTOL and STOL aircraft. The "current" CTOL aircraft considered utilizes the Pratt & Whitney JT8D-15 engine rated at 15,500-pound sea level thrust. The "new" CTOL and STOL aircraft incorporates a Detroit Diesel Allison PD287-43 advanced turbofan engine rated at 15,350-pound sea level thrust. The exhaust emissions from these engines were computed over a number of selected landing and takeoff (LTO) cycles established by the Environmental Protection Agency (EPA) for commercial turbine-powered aircraft operating from major airports; Aerospace computed these emissions for CTOL and STOL aircraft operating from small, noncongested suburban airports.

(1) Emission Characteristics

Emission indices were established for each aircraft and for operating modes considered in various LTO cycles. The analysis was limited to the following three pollutant species, each having been given prime consideration in air quality analyses: carbon monoxide (CO), hydrocarbons (HC), and oxides of nitrogen (NO_x). A number of additional species are also potentially harmful to human health, including the oxides of sulfur, aldehydes, and different types of particulate matter (smoke). Very little information is currently available on the concentrations of these species in the aircraft gas-turbine exhaust. Except where otherwise stated, all emission indices and fuel consumption data presented are for one engine, not for the total aircraft. The indices and the fuel flow rates are presented in Table A-13 for the taxi-idle, takeoff, climbout, and approach modes used in the various LTO cycles considered in the study.

The Pratt & Whitney JT8D-15 engine is the latest commercially available engine of the JT8D turbofan engine family. This group, including the JT8D-1, -7, -9, and -11 designs, consists of a multistage axial compressor, an axial fan, and a multistage axial turbine. The engines

Table A-13. Engine Emission Indices

LTO-Cycle Mode	% of Rated Thrust	Pratt & Whitney JT8D-15				Allison PD287-43 (4% Bleed)			
		Fuel lb/hr	lb/1000 lb Fuel			Fuel lb/hr	lb/1000 lb Fuel		
			CO	HC	NO_x		CO	HC	NO_x
Takeoff	100	9438.5	1.08	0.22	25.93	3824.2	2.75	0.45	19.57
Climbout	90	-	-	-	-	3186.8	3.15	0.51	18.43
	85	7797.0	1.44	0.23	19.77	2931.9	3.38	0.55	17.91
Approach	50	-	-	-	-	1779.3	5.78	0.79	14.35
	40	3707.1	5.66	0.56	8.53	1540.3	7.05	0.87	13.37
Taxi-Idle	6	1019.3	58.00	8.48	3.07	378.2	38.50	2.85	4.60
	6	-	-	-	-	378.2	89.47*	6.42*	4.25

*No bleed flow.

have identical geometry but have different compressor pressure ratios, rotational speeds, and turbine-inlet temperatures. Since exhaust emissions test data are not currently available from JT8D-15 production engines, a study was made of all available emission data from the JT8D engine family in order to estimate the needed JT8D-15 emission characteristics. The best collection of JT8D engine-emission data is contained in a report published by Cornell Aeronautical Laboratory (CAL) in 1971 Ref. 13). The data presented in the CAL report were taken in 1971 by the Bureau of Mines on American Airlines engines and by the Southwest Research Institute (SWRI) on TWA engines, both under contract to EPA. The Bureau of Mines data are from JT8D-1, -7, and -9 engines incorporating smokeless combustors, and from -1 and -7 engines with regular combustors. The SWRI data are from JT8D-1 and -7 engines fitted with regular combustors and JT8D-9 engines fitted with smokeless combustors.

Additional data included in that report were provided to the Environmental Protection Agency by Pratt and Whitney.

The JT8D engine data indicate that the NO_x emission index tends to increase (at constant CO) as engine thrust rating increases. A similar trend is observed between the HC and NO_x emission indices. According to these data, there is an inverse relationship between HC, CO emissions and the NO_x emissions produced by gas-turbine engines, trends which are in agreement with analytical predictions. At high thrust levels, the combustor air inlet and exhaust temperatures are high, resulting in high NO_x and low HC and CO emission levels. With decreasing thrust, the NO_x emissions decrease while CO and HC emissions increase. Based on the trends observed, the Pratt and Whitney JT8D experimental engine data were selected to represent the JT8D-15 engine. Both engines are rated at 15,500-pounds thrust.

The emission indices and fuel flow rates of the Allison engine were provided by Allison. According to Allison, the emission indices and specific fuel-consumption data are applicable to all PD287-43-type engines with rated thrusts above 6000 pounds. The Allison PD287-43 engine is a commercial derivative of an engine now under development for the U. S. Air Force. The component operating conditions (listed in Table A-14) reflect the advanced state-of-the-art technology projected for the 1978/80 time period. In its current design stage, the engine has a high bypass ratio and incorporates a multistage axial fan and compressor, an advanced combustor and fuel injection system, and a multistage axial reaction turbine with blade cooling.

The original Allison data (Ref. 14) were for zero compressor-bleed flow and were based on test data from their development-prototype gas generator program. Allison recently updated these data to include the effects of bleed flow (Ref. 15). According to Allison, a 4-percent bleed-flow rate represents a reasonable estimate for this engine, but a more accurate bleed-flow rate will be determined after completion of the aircraft and engine designs.

Table A-14. Allison PD287-43 Turbofan Engine Parameters

Takeoff Thrust	Design Variable*
Total Pressure Ratio	20:1
Turbine Inlet Temperature	2400F
Bypass Ratio	2.8
Fan Pressure Ratio	3
No. of Compressor Stages	8
No. of Fan Stages	3
No. of Turbine Stages	5

* 15,350-pound thrust selected for Aerospace Study

Inclusion of bleed flow affects only the emissions of the taxi-idle mode. Since engine power increases when bleed flow is used, the CO and HC emissions decrease substantially while the NO_x emissions increase slightly. When these indices are multiplied by the fuel-flow rate at each throttle setting and normalized to the rated thrust at full throttle, the results shown in Figure A-25 are obtained. These data can be used to scale the emissions to concepts and sizes other than those specifically analyzed in this study, and they illustrate the full effect of throttle setting on the rate of emission output.

(2) Landing and Takeoff (LTO) Cycles

To account for the pollutants emitted into the atmosphere in the terminal area, various LTO cycles were followed between sea level and the 3,000-foot altitude. This regime has been judged by the EPA and other organizations to be of major importance because of the high pollutant-emission rates occurring during the LTO operation and of the simultaneous proximity to ground activities.

The landing and takeoff cycle generated by the EPA for turbine-engine-powered aircraft is shown in Table A-15 (Refs. 13 and 16). This

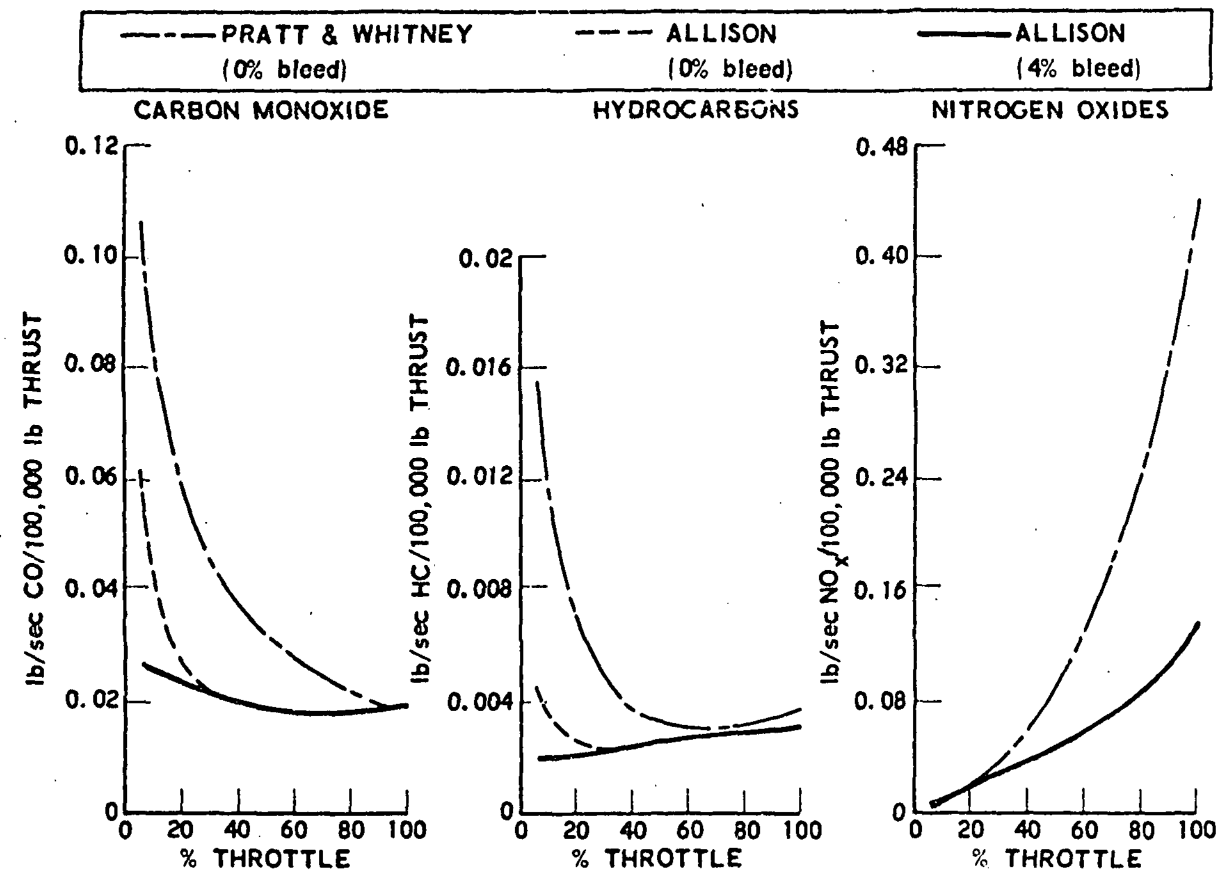


Figure A-25. Specific Pollution Index (lb/sec Pollutant per 100,000 lb Rated Thrust)

Table A-15. Landing and Takeoff Cycles for Turbine-Powered Aircraft

LTO-Cycle Modes	EPA/CTOL		Aerospace CTOL		Aerospace STOL	
	% Rated Thrust	Time in Mode: Minutes	% Rated Thrust	Time in Mode: Minutes	% Rated Thrust	Time in Mode: Minutes
First Taxi-Idle	6	19.0	6	3.0	6	3.0
Takeoff	100	0.7	100	0.5	100	1.0
Climb	85	2.2	100	1.87	100	1.57
Approach	40	4.0	40;50	4.35	50	3.74
Last Taxi-Idle	6	7.0	6	3.8	6	5.0

cycle was established by the EPA from time-in-mode analyses of high activity periods at major domestic airports. The time-in-mode and engine-power settings in the various aircraft-operating modes were obtained by the EPA from a number of engine manufacturers, air frame manufacturers, airline operators, and the FAA. The first taxi-idle mode includes the total elapsed time between engine startup and initiation of the turn of the aircraft onto the runway. The approach and climbout modes cover an altitude between sea level and 3,000 feet. The last taxi-idle mode includes the time between completion of the landing and engine shutdown at the terminal. Transient operating periods of the engine during takeoff and landing are not considered separate operating modes, but they are included in the takeoff and approach modes of the EPA cycle. The small duration of the transient periods and the lack of emission data for these operating conditions justify this approximation.

The LTO cycle data projected by The Aerospace Corporation (Table A-15) are based on trajectory limits previously described in Section A.1 and are for CTOL and STOL aircraft operating from small suburban-type airports.

The principal differences between these cycles and the EPA cycles are the shorter taxi-idle modes used by The Aerospace Corporation.

(3) Comparison of Effects

The predicted exhaust emissions of the Pratt & Whitney and Allison engines using the EPA-LTO cycle are presented in Table A-16. Comparison of the data for comparable LTO cycles indicates that the CO, HC, and NO_x emissions of the Allison engine are substantially lower than those computed for the Pratt & Whitney engine. For example, the CO, HC, and NO_x emissions of the Allison engine when operated with 4-percent compressor bleed are approximately 27, 16, and 41 percent, respectively, of emissions computed for the Pratt & Whitney engine. However, in making comparisons of this kind, one must take into consideration that the Pratt & Whitney engine represents a commercially available engine designed with current state-of-the-art technology, whereas the Allison engine represents a design incorporating more advanced technology. Pratt and Whitney would likely be able to match the emission and specific fuel consumption characteristics of the Allison engine with a new engine design.

Table A-16. Turbofan Design Effects
EPA/LTO Cycle

Engine Type	Pounds per Cycle		
	CO	HC	NO_x
Pratt & Whitney JT8D-15	27.54	4.00	11.97
Allison PD287-43 (w/o Bleed)	15.87	1.22	4.87
Allison PD287-43 (4% Bleed)	7.52	0.64	4.93

The effects of differences between the EPA-LTO cycle and that of Aerospace are evident from Table A-17. These differences derive almost entirely from differences in taxi-idle time prior to takeoff. The increase of approach thrust from 40 to 50 percent causes a 10-percent increase in NO_x in the Aerospace LTO cycles.

Table A-17. LTO-Cycle Effects
Allison PD287-43 Turbofan Engine 4-percent Bleed

LTO-Cycle	Pounds per Cycle		
	CO	HC	NO_x
EPA (40% Approach Thrust)	7.52	0.64	4.93
Aerospace CTOL (40% Approach Thrust)	2.85	0.28	4.65
Aerospace CTOL (50% Approach Thrust)	2.82	0.29	5.02

Emissions generated by the Allison engine over an entire LTO cycle are shown in Table A-18 normalized to the actual impulse delivered. EPA goals for the same measure are also shown, and it is evident that the level of carbon monoxide output by the Allison design at 4-percent bleed still exceeds these goals. The pollution difference deriving from CTOL and STOL design differences are shown in Table A-19. Applying the Aerospace cycles for both CTOL and STOL to the Allison engine by itself produces relatively little impact on the emissions per LTO cycle per engine. However, for a 150-passenger aircraft, four of these engines are required for STOL as opposed to three for CTOL, leading to a corresponding increase in total aircraft emissions per LTO cycle.

The influence of taxi-idle time before takeoff (ground time) on the aircraft emissions using both engines is shown in Figure A-26. There exists little question that STOL can operate within the 3 minutes nominally allocated. The substantial reductions in emissions achieved by STOL over current CTOL operations are made possible by the technology represented in the Allison design. If that same technology is used in a new CTOL aircraft, even further reductions can be realized.

Table A-18. Emission Levels and 1979 EPA Goals
EPA/LTO Cycle

Condition	EPA Emission Index (lb/1000 lb Thrust-Hour)		
	CO	HC	NO_x
Allison Engine without Bleed	11.437	0.871	3.459
Allison Engine with Bleed	5.440	0.452	3.500
EPA 1979 Goals	2.000	0.400	3.250

Table A-19. CTOL/STOL Differences
Allison PD287-43 Turbofan Engine
4% Bleed: 50% Approach Thrust
150-Passenger Aircraft

Aircraft	Trajectory Effects (lb/Cycle/Engine)			Design Effects (lb/Cycle/Aircraft)		
	CO	HC	NO_x	CO	HC	NO_x
STOL	3.03	0.31	5.03	12.1	1.22	20.1
CTOL	2.82	0.29	5.02	8.5	0.87	15.1

A.2 STOLPORT REQUIREMENTS

The terminal area provides the interface between the aircraft and the using and nonusing public. It should be designed to handle the required level of air traffic safely and efficiently, to process the air traveler with minimum disruption to his trip, and to be virtually transparent to the nonusing public. Total airport terminal-area requirements are determined by the size and configuration of aircraft and the number of annual passengers expected. In this study, however, only the land, facilities, or improvements explicitly required to support a commercial STOL service were charged against the STOL system.

In the following discussion a distinction is made among three kinds of facilities: (1) airfield, (2) terminal, and (3) noise buffer zones. The airfield includes the runways, taxiways, lighting, and other facilities related

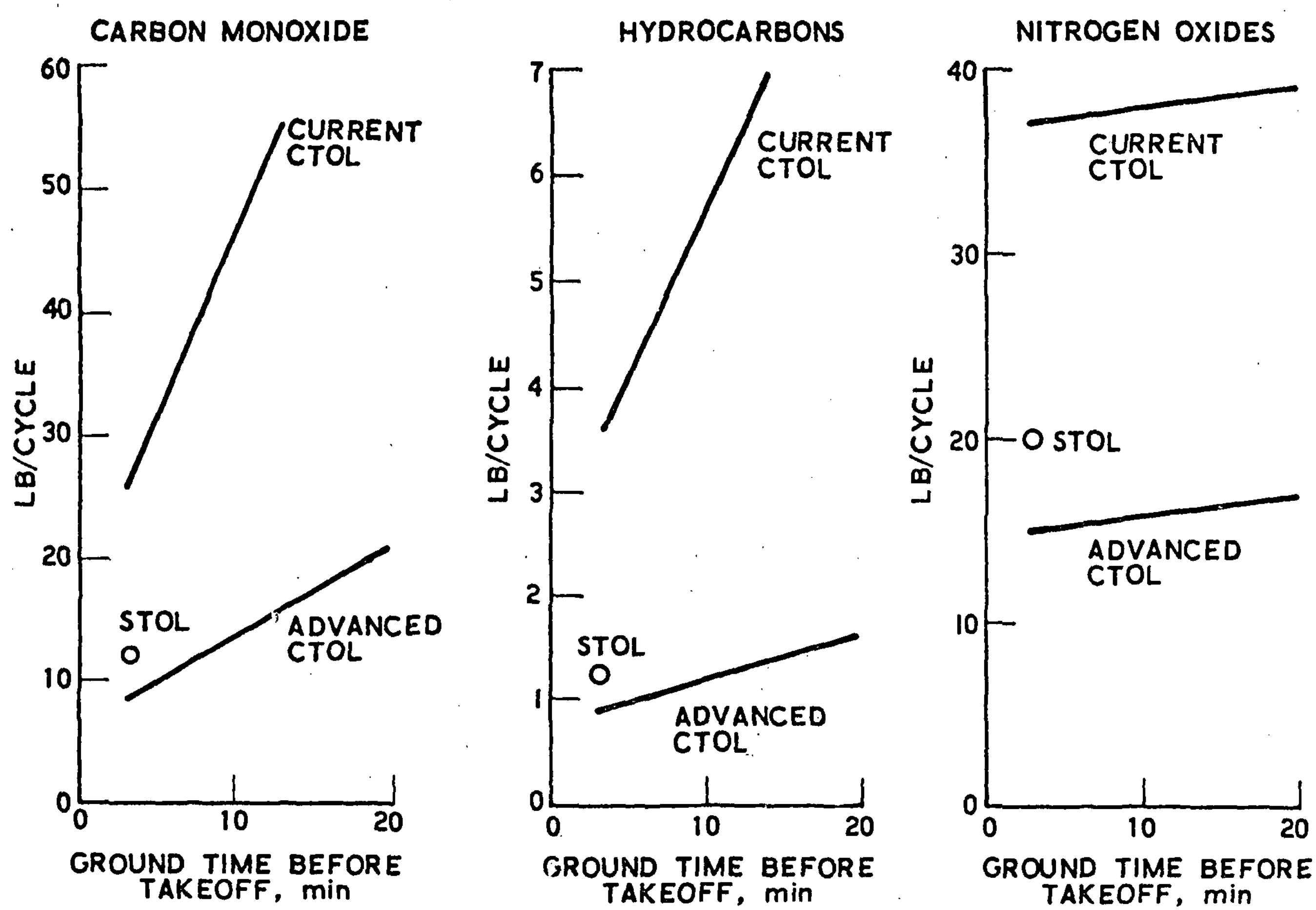


Figure A-26. Takeoff Taxi-Time Effects

to the landing and takeoff of aircraft. The terminal includes the parking apron and terminal building. Terminal capital costs are determined by building size and the apron required to accommodate forecasted traffic. Noise buffer zones include the land purchased or modified in terms of usage to alleviate the noise impact of aircraft operations on both the nonusing and the using community.

a. Airfield

Required hot day runway and taxiway lengths of 2000 feet were defined by the design parameters of the Augmentor Wing STOL Aircraft. Runway width was taken as 100 feet (Ref. 18) and the taxiway width as 60 feet (Ref. 19). The runway thickness is a function of three elements: soil bearing strength, runway composition, and aircraft gross weight and landing gear arrangement. Pavement thicknesses are taken from Ref. 20, assuming an Augmentor Wing STOL with dual-tandem landing gear arrangement. Figure A-27, taken from Ref. 20, shows gross weight as a function of pavement thickness for a number of soil groups. The appropriate soil group must be determined for each port. When not determined, subgrade classification F5 was used in this study. Also, all airfield requirements were computed on the basis of flexible pavements (i.e., asphalt). For a STOL-port located on an existing airport, the existing airfield thickness was subtracted from the required thickness to establish the amount of augmentation needed.

Several ports required extensive site preparation. Two examples were Secaucus (a new port in the New Jersey meadowlands west of New York City) and India Basin, in a San Francisco redevelopment area. The condition of the Jersey meadowlands required the addition of substantial amounts of fill followed by soil compaction operations. The India Basin location, because of its proximity to San Francisco Bay, needed the addition of expensive support pilings. Estimated costs of labor and materials are included in the total chargeable costs of these ports.

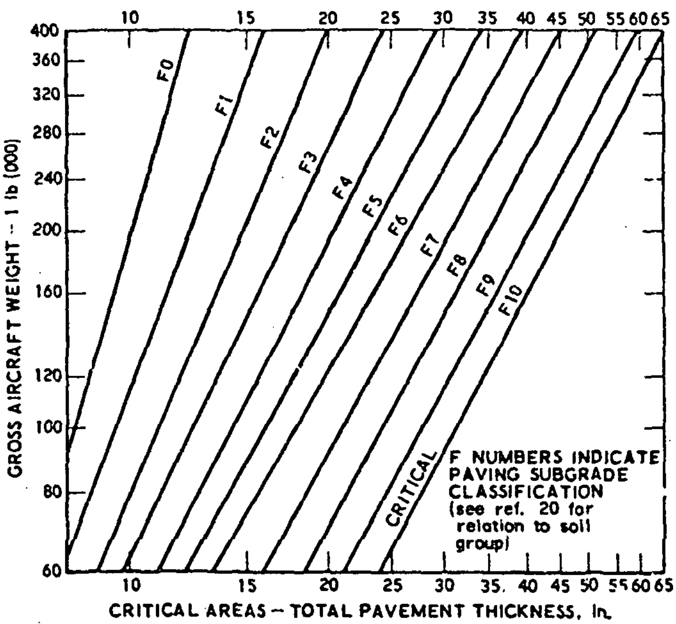


Figure A-27. Design Curves, Flexible Pavement
Dual-Tandem Gear

b. Terminal

The required terminal size was found by modifying FAA guidelines for terminal area floor space (Ref. 21). The FAA area requirements are expressed as a function of peak-hour passengers. In this study, peak-hour passengers were determined as the maximum of either 10 percent of average daily passengers times a peaking factor or average daily passengers per aircraft movement times a peaking factor. The peaking factor (1.29) is the ratio of the peak season or day's level of scheduled operations to the average level of operations. The first part of the formulation is based on the diurnal distribution of short-haul passengers. The second part of the peak-hour passenger formulation is necessary for cases where less than 10 departures occur per average day.

Terminal floor space requirements, obtained from Ref. 21, were derived for each of six elements, including:

- The Passenger Service Area. This area normally includes facilities for ticketing, reservations, and baggage weighing/checking. As defined in Ref. 21, it also includes the counters provided for passenger services but does not include the areas behind the counters. These spaces are part of the airline operations area. The passenger service area includes some limited seating as well, provided primarily for the convenience of aged and disabled persons. Current developments in ticketing and baggage handling systems will simplify and speed these processes, but they will not necessarily reduce the required service area. Therefore, for this study, the passenger service area recommended by the FAA in Ref. 18 was used without adjustment.
- Airline Operations Area. This area includes space behind the passenger counter and space for reservations, communications, baggage handling systems, load control, dispatching, management, and employee necessities. Part of this space must provide a view of the aircraft loading apron and a direct connection with it. Areas recommended by the FAA include minor express and cargo space and airline-operations space for multiple-carrier occupancy. In the interest of efficient use of space, and to facilitate passenger and baggage flow through the terminal, it has been assumed that all carriers servicing the airport share facilities and services wherever possible. A 20-percent reduction of the FAA-recommended airline operations area was used for STOLports.
- Baggage Claim Area. This area should be located as closely as possible to the passenger-vehicle loading area so as to minimize passenger baggage handling. Short-haul systems with a high percentage of commuter traffic (compared with the average airline, which provides the statistics for the FAA-recommended areas in Ref. 21) can be expected to handle a smaller number of bags per passenger. The FAA-recommended baggage claim area was therefore reduced by 20 percent.
- Passenger Waiting Areas. These areas should be adjacent to the aircraft boarding gates and should permit easy access to the passenger service area. The FAA-recommended values were used without adjustment.
- Dining and Kitchen Facilities. These are patronized by passengers, visitors, and (at least where a coffee shop or cafeteria is provided) by airport employees. Assuming the higher-than-average percentage of commuter traffic for short-haul systems

described above, it is probable that fewer than the average number of visitors will be involved. It is also unlikely that a commuter would be willing to spend much time dining. The FAA-recommended areas for dining and kitchen facilities were reduced by 50 percent.

- Concession Areas. These areas not only provide floor space for news, novelty, and gift facilities but also include space allowances for parcel lockers, a telegraph office, an insurance counter, auto rental facilities, etc. FAA-recommended areas were used without adjustment.

Figure A-28 depicts the FAA-recommended floor areas for each element, with no adjustment for short-haul system characteristics. Total required terminal floorspace for STOLports was obtained by the summation of the six elements listed above, appropriately modified. Results showed that a linear fit of total area as a function of peak-hour passengers was possible, resulting in required STOLport terminal floor space of 80 square feet per peak-hour passenger.

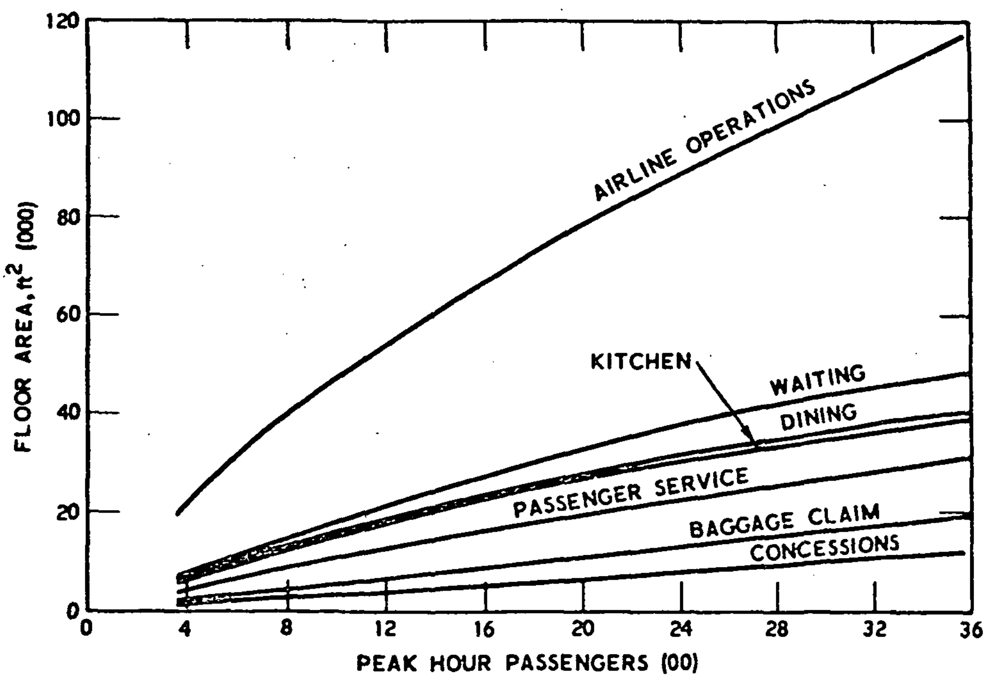


Figure A-28. Terminal Building Area Requirements, FAA Data

In addition to the terminal-building floorspace requirements, the gate position area adjacent to the terminal is also derived on the basis of peak-hour operations. The length and width of aprons were determined by taking 1.75 times the aircraft wingspan (Ref. 22). This allows room for the aircraft to maneuver into and out of the gate position. The apron thickness is the same as that required for the runway and taxiway. The apron pavement required was calculated from the data in Figure A-28 and the known relationships between span and capacity. The relationship between apron-paving requirement and vehicle capacity is approximated by:

$$\text{Apron paving, } (ft^3) = (402) \times \text{STOL aircraft passenger capacity}$$

The number of gates required at each port is found by the formula:

$$G = (T + 0.02) \times N$$

where "G" is rounded up to the nearest integer and

G = No. of gates

T = Aircraft turnaround time in hours (Section A.1.c.3)

N = No. of peak hour passenger departures

A time, (T), of 0.02 hours is allowed for an aircraft to maneuver into and out of the gate. Aircraft turnaround times developed in Section A.1.c utilized only a single door for enplaning and deplaning passengers. The relationship between average daily passengers and gate capacity is shown in Figure A-29. Gate requirements at each terminal are developed as a function of total passenger traffic, taking into account the peaking factor required to accommodate seasonal variations.

c. Noise Buffer Zones

A major facet in the analysis of a transportations system's viability is its impact on the noise environment within the vicinity of its ports. A method for quantifying the system's adverse noise impact in economic terms that are directly applicable to airline costs is through the determination of noise-buffer zone requirements in the port's vicinity, once an STOL airline

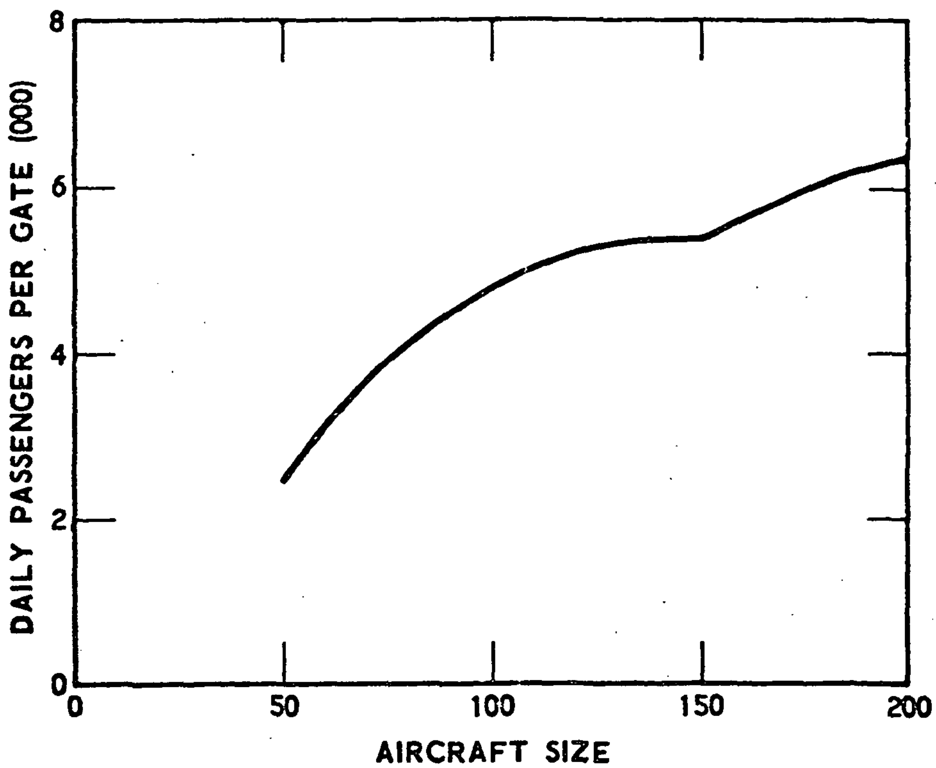


Figure A-29. Gate Capacity Limits

service has been implemented. The objective of creating noise-buffer zones is that of indemnifying owners of properties in the vicinity of STOLports from adverse effects of noise generated by STOL aircraft. Procedures were developed for estimating the cost to an STOL system of creating such a buffer zone. These costs are dependent upon:

- The amount, kind, and cost of properties affected
- The nature of the property rights acquired
- The potential revenue-producing uses of the property.

(1) Strategies for Buffer Zone Land Acquisition

There are two alternative strategies for the acquisition and ownership of property rights needed to provide a noise buffer zone. The first strategy might be designated "total acquisition," to denote a policy in which a public body acquires all property within a designated noise contour. Implementing this policy would require that the acquiring body possess the right of eminent domain. This would be the case if a public body were acting. But it would not be the case if the property were to be acquired by a private organization. Since there is no functional requirement for the property, other than that of providing a noise buffer zone, there is no need that ownership be of contiguous parcels. Moreover, acquisition by condemnation would place severe, virtually prohibitive, restrictions on the revenue-producing uses to which the land could subsequently be placed. As a rule, all redevelopment would have to be for directly airport-related activities.

The second strategy is one of voluntary acquisition, which could be exercised by either a public or a private body since no condemnation is involved. Under a voluntary program, the land acquisition agency would stand ready to purchase at fair market value any "noise affected" properties and to pay the original tenants for relocation costs. Such a voluntary program has the advantage that individuals and firms who prefer to remain may do so. In addition, the program may be carried out by a private agency, such as a realtor or developer. This latter method has three major advantages in facilitating future development of the acquired properties. First, since the property is not acquired by condemnation, the only restrictions on redevelopment are those generally applying to the community and to the requirement for noise compatibility of the new uses. Second, since the land is in private rather than public ownership, it can be subdivided to finance development. Finally, the possibility of political repercussions might be reduced if the redevelopment program were carried out by one or more private developers rather than if the public airport owner, alone, engaged in this essentially private activity.

The requirements for effecting the creation of a noise buffer zone include items other than purchasing land parcels within the zone at their fair market value. These items result in additional costs, and they are composed of six elements; namely:

- Environmental impact study. This includes the cost of public hearings.
- Housing cost differentials. If the cost of equivalent replacement housing exceeds the fair market value of the property taken for the noise buffer zone, U. S. Dept. of Transportation (DOT) rules allow outright grants to property owners to compensate for the differential. Tenants are also eligible for smaller grants to compensate for rent differentials (Ref. 23).
- Moving expenses. An additional DOT regulation allows for the paying of moving expenses based on the number of occupied rooms for each household (Ref. 23).
- Relocation assistance office. There is a Federal requirement that displacees of Federally funded projects be assisted in relocating. Thus, if Federal airport aid is involved in STOLport construction, a relocation assistance office is required.
- Small business interruption. A displaced small businessman is entitled to a grant for loss of business in lieu of moving expenses.
- Appraisal and acquisition management. Typically, land specialists are hired to appraise and acquire parcels for the noise buffer zone.

The determination of the required size of a noise buffer zone at a STOLport depends on three items:

- The noise contours produced by the aircraft operations at the STOLport
- The existing boundaries of the STOLport
- The land use of areas surrounding the airport's existing boundaries.

In this study, the STOL system was charged with the cost of that portion of the noise buffer zone which is attributable to the addition of STOL operations without any benefits being assumed for resale or converted use of the property. This was not done to reflect any particular method of

acquisition but rather to ensure that a conservative approach was used to estimate economic viability of the STOL system. As a practical matter, however, the noise level predicted for the Augmentor Wing aircraft is so low that noise-buffer-zone costs do not effect system economics.

(2) Noise Exposure Forecast

The impact of noise on the community immediately adjacent to an airport boundary was studied with the aid of a figure of merit called Noise Exposure Forecast (NEF). It was developed (Ref. 24) to combine the effects on observers of single-event aircraft flyby noise with the growing annoyance felt as the number of flyby events increases. In tests conducted by Bolt, Beranek, and Newman (Ref. 25) it was determined that observers in a residential environment found noise levels acceptable when NEF was 30 or less at the observation point. On the other hand, persons engaged in commercial businesses, as in shopping centers, were not unacceptably disturbed until they were in a location where NEF was 35 or greater; furthermore, observers in industrial enterprises found aircraft noise levels acceptable at locations where NEF was as high as 40. Thus, the acceptability of aircraft noise is closely related to the activities of affected individuals and, therefore, to the land uses in the airport vicinity.

The noise analysis performed in this study was directed at determining the extent of adverse aircraft noise impact on land adjacent to selected STOLports. NEF was adopted as the figure of merit for judging the acceptability of STOL aircraft noise levels. It is defined by the effective perceived noise level (EPNL) at the observer's location modified by a factor which accounts for the number of noise events to which the observer is exposed. The relationship is given by the formula

$$NEF = EPNdB + 10 \log_{10}(N_{day} + 16.67 N_{night}) - 88$$

where N_{day} is the number of noise events occurring between 0700 and 2200 hours, and N_{night} is the number of events in the period 2200 to 0700 hours. Night time events are weighted 10 dB more heavily than daytime events,

which partially accounts for the fact that the STOL systems examined in this study were designed to operate only during the period 0700 to 2200 hours. NEFs of 30, 35, and 40 were utilized to judge noise acceptability in residential, commercial, and manufacturing land-use zones, respectively. An adverse noise impact is said to exist when a parcel of land, or a portion thereof devoted to a particular use, is contained within the limiting NEF contour.

For the purposes of this analysis, the buffer zone was defined as that portion of the land area lying within an NEF = 30 contour which may be attributed to STOL vehicle operations. Thus, to compute the costs associated with the acquisition of property needed to develop the buffer zone, it was first necessary to compute the STOL noise impact and then to distinguish the types of land uses in the adversely impacted area. An algorithm was established on the premise that residential property could not exist within the NEF = 30 contour, but such property could be converted to commercial uses so long as NEF = 35 was not exceeded and to manufacturing uses so long as NEF was not greater than 40. Furthermore, the computational process was mechanized so that many STOL system alternatives could be analyzed at a number of diverse ports.

(3) Noise Impact Model

To study the details of STOL system-related noise impact, a computer-based approach was developed for determining the areas of land parcels contained within prescribed constant-NEF contours, then finding the STOL system portion of potential buffer zone costs. The computer program contains three major elements:

- A routine for prescribing the airport scenario to be studied in terms of aircraft mix, associated EPNdB as a function of slant range from aircraft to observers on the ground, and approach and departure trajectories flown by each aircraft type considered.
- A data processor for computing X-Y coordinates of prescribed constant noise acceptability (i.e., constant NEF) contours.

- A land-use model for graphically describing land uses on and around the airport, to whatever degree of detail is required (even down to single-family dwellings) and on which are superimposed precomputed NEF contours to determine the areas and values of adversely affected zones.

The airport scenario and noise-data processor models were modified from a computer program obtained from the Transportation Systems Center (TSC, Ref. 26) to better meet the needs for explicit data on coordinates of prescribed NEF contours and to more accurately consider the directionality effects of noise from Augmentor Wing STOL aircraft. Land uses in the vicinity of the airport were established through a combination of tax book data, census tract data, real estate and planning commission information, aerial photographs, and personal visits to the locale under analysis. Finally, a method for digitizing the derived land-use information and providing an interface with the NEF contour program was developed.

(4) Land Use Data

The approach to developing land-use data involved the examination of aerial photographs in conjunction with United States Coast Guard and Geodetic Survey's 7-1/2^{o} quadrangle charts. The aerial photographs permitted identification of land uses in the airport's immediate vicinity; the quadrangle charts were used to determine zonal coordinates. After an initial land-use description was developed by this method, a visit was made to the area; real estate and planning data, census tract information, and tax book data were examined. In this way a final land-use zone map was drawn, and average values were ascribed to the land in each zone.

Figure A-30 shows a typical aerial photograph used in the land-use identification process. The airport in the figure is Sacramento Executive, and the localizer runway may be clearly identified by its distinctive markings. Airport boundaries are also clearly delineated. (Indeed, this photograph notes the almost surprising encroachment of residential land uses immediately adjacent to the port.) In addition to identifying diverse land uses by studying the photographs, it is often possible to separate high density from low density

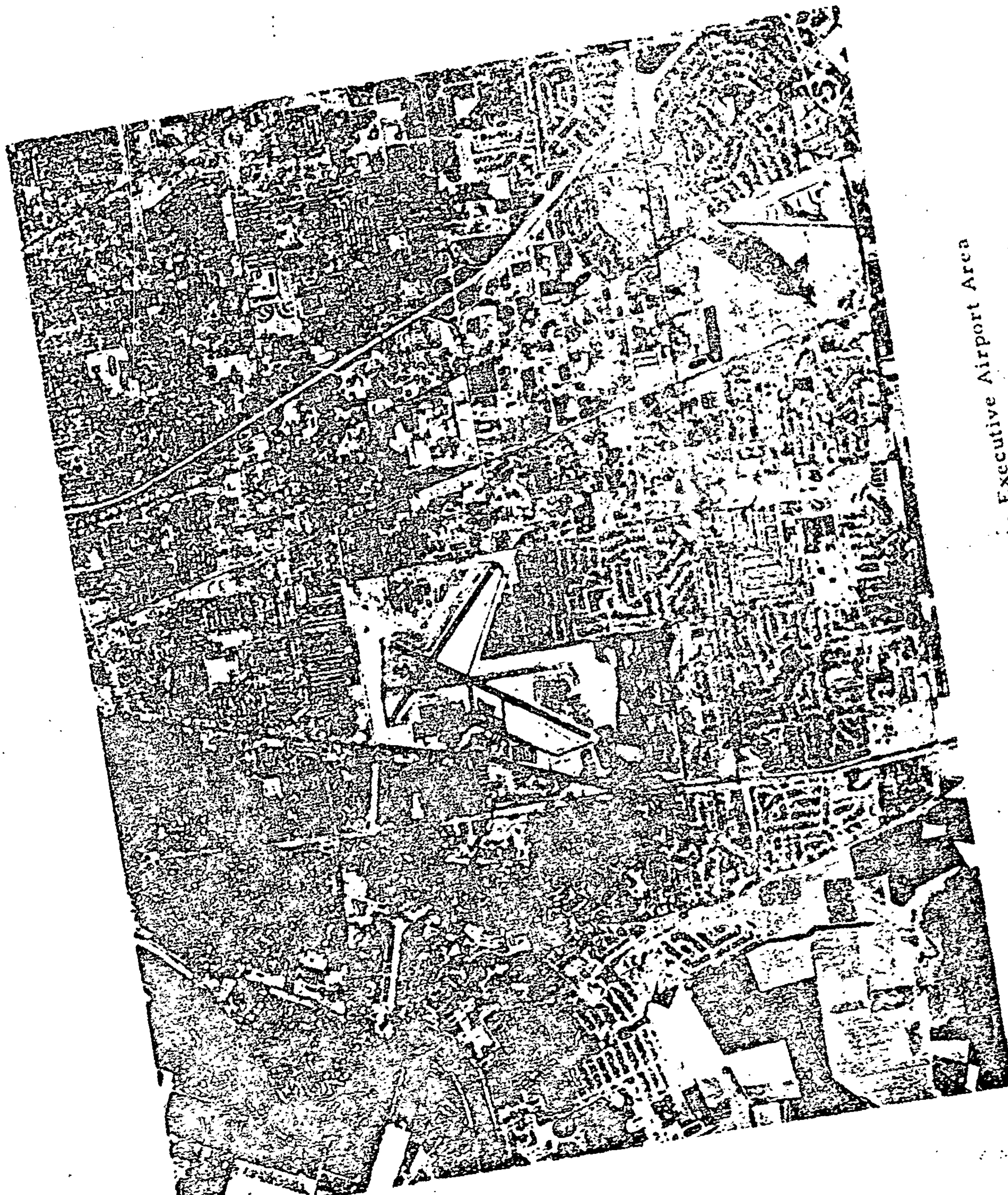


Figure A-30. Sacramento Executive Airport Area

single-family housing tracts and also from apartment-house areas. Shopping centers and manufacturing zones are easily identified, as well.

Figure A-31 shows the result of the land-use identification process. The computer-generated plot in this figure is of the area around Sacramento Executive Airport. Zones coded "R" are residential, those coded "S" are commercial, and those identified by "W" are manufacturing. Open or unzoned land is coded "Z" to indicate that no dollar value is associated with it for a development of buffer zone costs. The airport is coded "ZA" and shown separately in Fig. A-32. One use of the real estate and planning commission data is to identify planned developments. Thus, some zones are coded "RP", indicating that the zone will eventually be developed as residential. The land use data stored in the computer are available to the user in report form as well as in the plotted format shown. The report consists of a listing of each zone, its area and its average value per acre.

The interface with the DOT/TSC noise contour program in essence "overlays" the noise contours onto the land-use map and, by means of a matrix comparison technique, locates intersections between contours and corresponding land parcels. Impacted areas in each parcel are computed within the NEF = 40 contour and between the NEF = 35 and 40 and NEF = 30 and 35 contours, thus providing the basis for computing buffer zone costs purely in terms of land-acquisition costs or, in a more sophisticated format, considering land-use changes and peripheral costs as well. The latter were described in detail earlier and included such elements as household moving expenses, business interruption expenses, housing cost-differential allowances, special costs associated with land acquisition, environmental impact reporting expenses, and costs associated with the need for a central relocation-coordinating office. This process is repeated both with and without STOL operations, with the cost difference ultimately being charged to the STOL operator. The output of this portion of the computer program is so formatted as to interface directly with the port-related indirect operating cost (IOC) computations described in Appendix A.3.d.

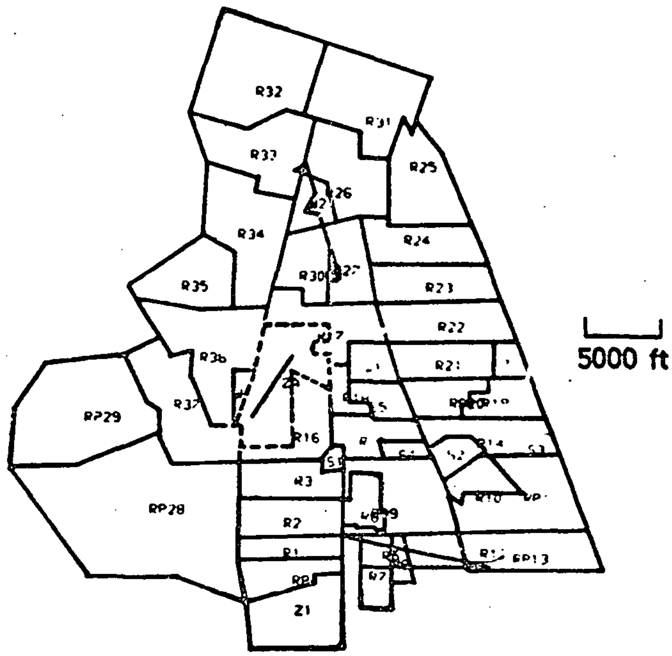


Figure A-31. Sacramento Executive Airport

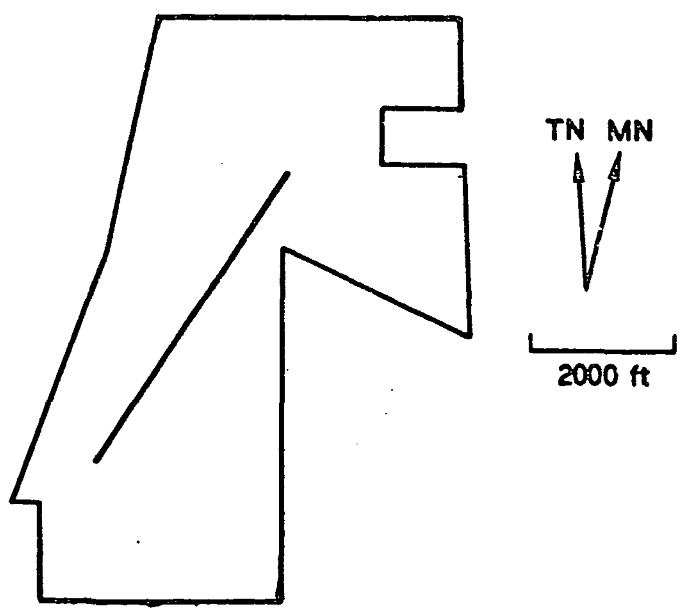


Figure A-32. Sacramento Executive Airport Area Land Uses

A. 3 ECONOMIC ANALYSIS

In this study, system operational characteristics were predicated on maximizing demand while achieving economic viability and maintaining environmental compatibility. This approach necessitated development of an economic analysis model that defined return on investment (ROI) as a function of STOL system characteristics while reflecting the costs of maintaining environmental compatibility. The resulting economic model consisted of three major elements:

- Identification of STOL operator investment requirements
- Determination of STOL system profit potential
- Derivation of ROI.

This section presents the essential economic inputs used in the study. Total airline-system investment was developed from flyaway cost, aircraft spares, and ground equipment. The operating cost structure, both direct and indirect, are delineated. Separate IOC structures were derived for intrastate and interstate operation. The cost basis and method of allocation of STOLport development costs are presented, and the place and use of ROI is explained. All economic items in the study were expressed in constant 1970 dollars so as to be comparable and consistent. The interaction of the various elements comprising the economic analysis program is illustrated in the flow diagram of Figure A-33.

a. Aircraft Unit Costs

The first element in determining flyaway cost was the estimation of production quantities as a function of STOL aircraft capacity. The basis was The Aerospace Corporation study of V/STOL Aircraft Implementation (Ref. 27). Engine production quantities were obtained by assuming five engines per airframe (four plus 25 percent spares). Variable production quantities were used to provide a variation in development-cost amortization as vehicle size was changed.

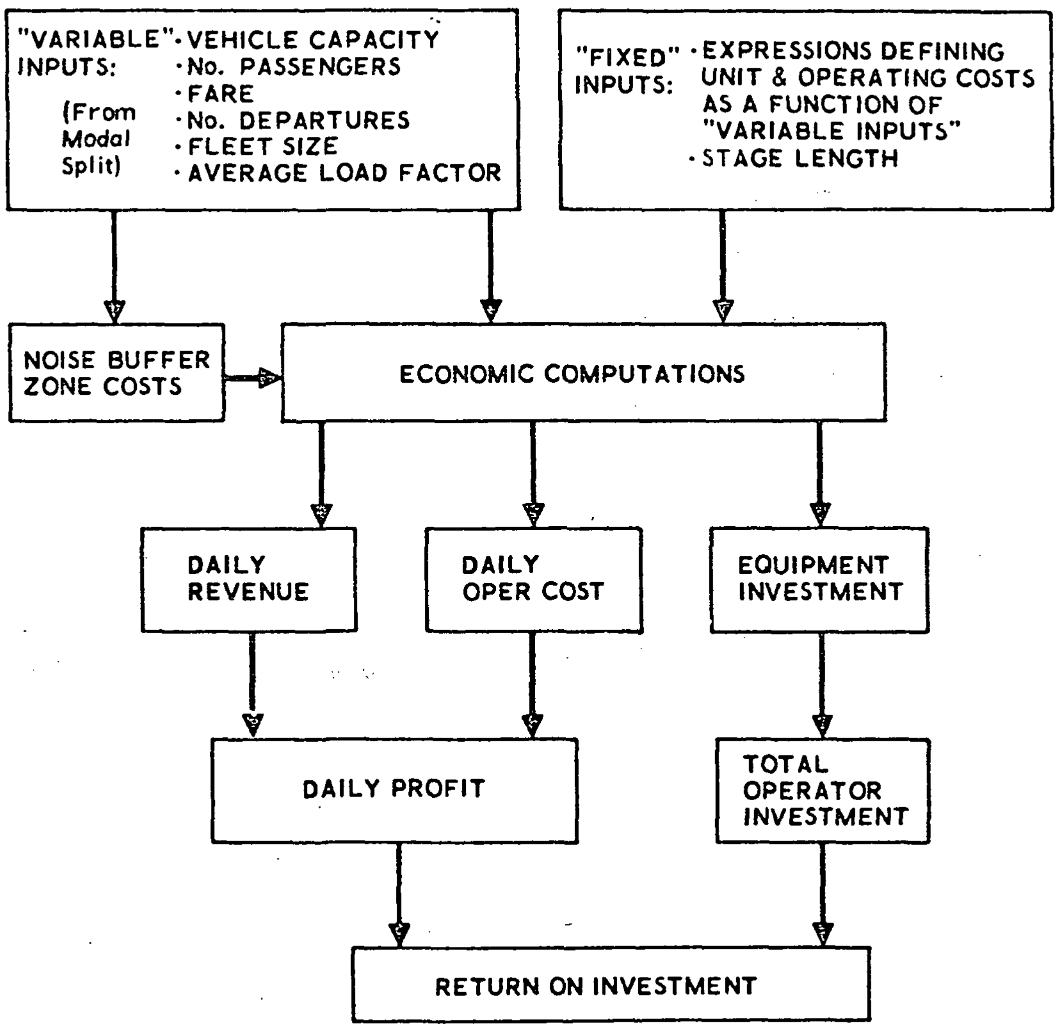


Figure A-33. Economic Model Data Flow

The airframe development costs were estimated by studying CTOL airframe development costs. The analysis utilized inputs of historical and (estimated) future airframe development costs for CTOL aircraft from U. S. airframe manufacturers. These data were examined and combined on the basis of aircraft weight, design range, and capacity, then adjusted for estimated level of advanced technology. The resulting curve fit was used to produce a relationship between capacity and development cost. The total and unit airframe development costs are shown in Table A-20.

Cost-estimating relationships covering aluminum and composite structural materials as well as equipment and controls were developed. The resulting costs per pound for these components are illustrated in Figure A-34 as a function of component weight. The cost relationships corresponding to this study's Augmentor Wing vehicles are highlighted on the figure. To determine unit cost as a function of production quantity, the foregoing costs (which were based on an average quantity) were multiplied by 2.644 (Ref. 28) to obtain a first-unit cost, assuming a 90-percent learning curve. An expression for average cost was obtained by means of a data fit, yielding the equation

$$\text{Average airframe unit cost (\$)} = (\text{first airframe unit cost}) \times (0.705^{\log n}),$$

where

n = quantity of airframes produced

The resulting airframe manufacturing unit costs are shown in Table A-20.

Engine development and manufacturing costs were combined in data developed by Allison Division of General Motors Corp. (Ref. 29). Cost items included in the engine unit costs involve those for development through aircraft flight certification. The basic development program for each engine included:

- 6000 hours of engine testing prior to type certification
- 5000 hours of component rig tests
- 200 hours of airborne flight testing
- 32 preproduction engines to be delivered
- 7 years of follow-on development and product support after type certification.

Table A-20. Airframe - Development and Manufacturing Costs

Aircraft Capacity	Total Cost Airframe Development ($ Millions)	Estimated Airframe Production Base*	Cost Per Airframe Development ($000)	Cost Per Airframe Manufacturing ($000)
50	200	976	205	2442
60	220	813	270	2756
70	240	697	344	3065
80	260	610	410	3371
90	280	542	517	3673
100	300	488	615	3971
110	320	444	721	4265
120	340	406	837	4555
130	360	375	960	4843
140	380	348	1092	5125
150	400	325	1231	5404
160	420	305	1377	5679
170	440	287	1533	5951
180	460	271	1677	6264
190	480	257	1868	6483
200	500	244	2049	6743

*(Ref. 27)

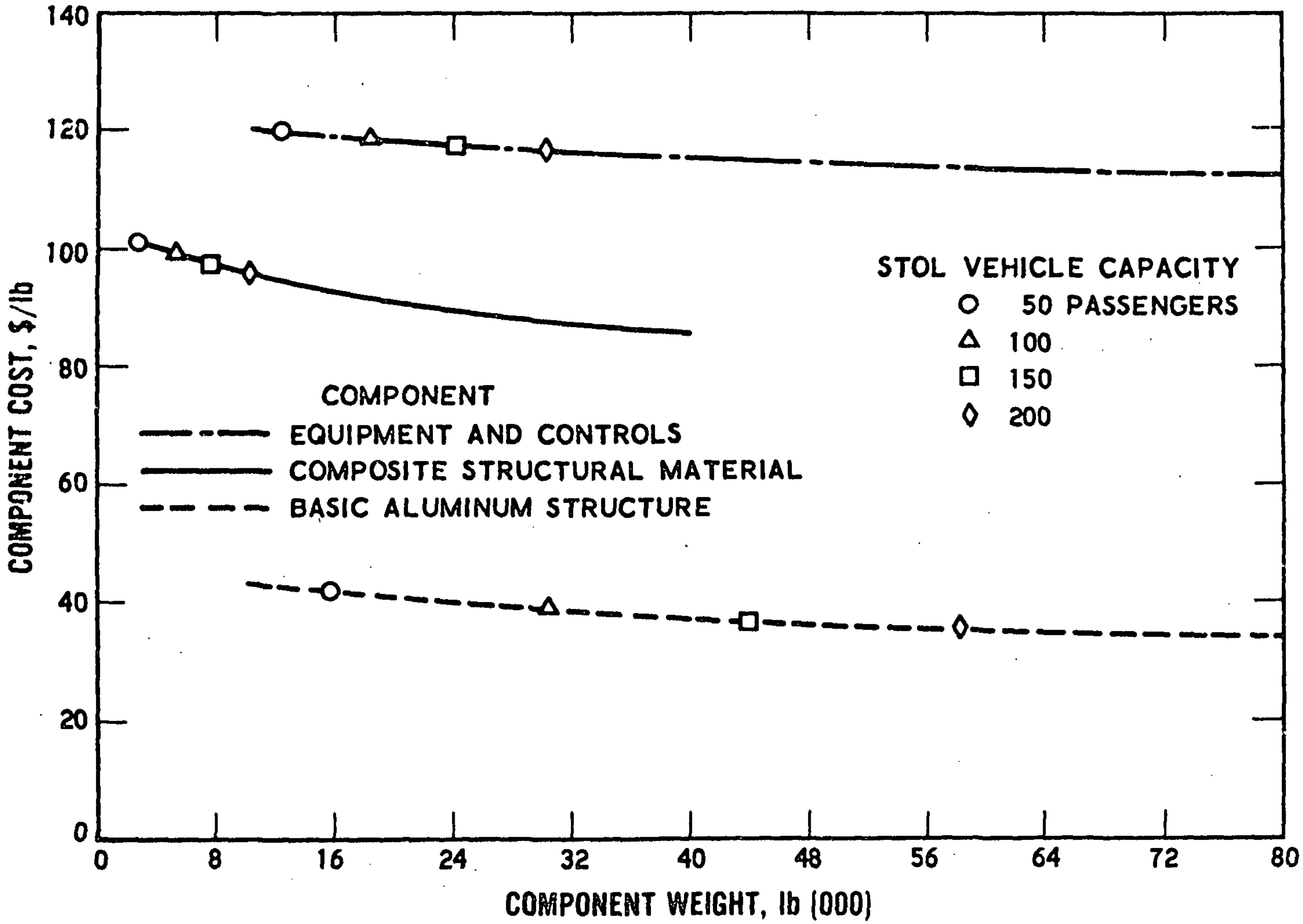


Figure A-34. Cost-Estimating Relationships

The development costs were based solely on commercial programs. The Allison data provided separate development costs for only three engine-thrust levels, shown below in 1970 dollars (all Allison cost data were in 1972 dollars, and conversion to 1970 dollars was necessary).

Thrust (lb)	Development Cost ($ Millions - 1970)
8,000	112
20,000	135
30,000	149

Engine unit costs are shown in Table A-21.

The combined airframe development and manufacturing costs, the costs of a set of four engines, and the total average flyaway cost of each aircraft are summarized in Table A-22.

In addition to flight-equipment investment costs, allowances must be added to account for ground facilities and equipment. Flight-equipment investment is defined as aircraft flyaway cost, plus spares, multiplied by fleet size. Spares are 10 percent of the airframe value and 30 percent of the engine value. Ground facility and equipment investment is accounted for by an added factor (variable by arena) of total flight-equipment investment. The ground-equipment investment factors by arena are displayed below.

Arena	Factor
California Corridor	0.13
Northeast Corridor (NEC)	0.16
Midwest Triangle	0.16

The factor for the NEC and Midwest Triangle is derived from U.S. domestic trunk-airline data (Ref. 30). The California Corridor factor is from Pacific Southwest Airline (PSA) data (Ref. 31). Probable reasons for the higher

Table A-21. Engine Unit Cost
Development and Manufacturing

Aircraft Capacity	Estimated Engine Production Base	Engine Unit Cost ($000)
50	4880	278
60	4065	321
70	3485	344
80	3056	388
90	2710	414
100	2440	437
110	2220	458
120	2030	478
130	1875	496
140	1740	517
150	1627	531
160	1525	547
170	1435	563
180	1355	577
190	1285	592
200	1220	660

Table A-22. Augmentor Wing STOL Flyaway Cost

Aircraft Capacity	Flyaway Costs ($000)		
	Airframe	Engines (4 per Aircraft)	Total
50	2647	1112	3759
60	3026	1284	4310
70	3409	1376	4785
80	3781	1552	5333
90	4190	1656	5846
100	4586	1748	6334
110	4986	1832	6818
120	5392	1912	7304
130	5803	1984	7787
140	6217	2068	8285
150	6635	2124	8759
160	7056	2188	9244
170	7484	2252	9736
180	7961	2308	10269
190	8351	2368	10719
200	8792	2424	11216

figure for the domestic trunks are their lower average density o. operations per port and their requirement for more equipment for adverse weather conditions.

b. Direct Operating Costs

Direct operating costs (DOCs) relate to flight equipment (including spare parts) depreciation, hull insurance, flight crew, fuel, oil, and maintenance (including maintenance burden). Excluded are other such aircraft-related variable costs as landing fees and cabin crew costs. This is the general industry definition of DOC and was the definition used for this study.

(1) DOC Formula Modifications

The Boeing 1971 DOC formula (Ref. 32) was used as the DOC basis with appropriate modifications to reflect STOL operations. The Boeing values for DOC items are given in 1970 dollars and were utilized with the following modifications:

- Fuel cost - A fuel cost of $0.121 per U.S. gallon was used vs $0.095 per U.S. gallon, to reflect arena fuel costs that are higher than the Boeing figure.
- Hull Insurance - Two percent of the flyaway cost was used vs 1 percent from Boeing, to reflect the higher insurance cost incurred with the introduction of a new aircraft type.
- Maintenance - A 30-percent STOL maintenance factor was added to the Boeing maintenance cost formula. This reflected the higher maintenance cost expected from a vehicle with complex lift devices.
- Flight Crew - The Boeing formula for three-man domestic jet flight crews was adopted for all STOL aircraft capacities used in this study.
- Spares - The Boeing figure of 30 percent of engine value was used for the engine spare parts factor. The airframe spare parts factor was increased from the Boeing figure of 6 percent to 10 percent of airframe value to be consistent with the assumed higher STOL maintenance cost and to reflect the increased holdings of required airframe spares.
- Depreciation - The CAB depreciation rule of 14 years and a 2-percent residual value was used vs the Boeing figures of 12 years and a 10-percent residual.

- Utilization - A new utilization (hrs/yr) formula was developed based on block time, turnaround time, length of the operating day, and ratio of peak and off-peak operations. The formula is:

$$UTIL = \frac{BT}{BT+T} \times HPY$$

where

UTIL	=	Annual utilization (hr)
BT	=	Block time (hr)
T	=	Average aircraft turnaround time (hr)
HPY	=	Hours per year available for utilization, based on an average operations day of 14-1/2 hours.

The HPY term reflects the constraints of planned periodic maintenance of aircraft, airport curfews and problems of scheduling operations to ensure compliance with these curfews, the relative level of off-peak to peak operations and the proportion of each, and the schedule-completion factor (which allows for weather-induced cancellations and unscheduled maintenance). The values of HPY by arena are:

Arena	HPY
California Corridor	4120
Northeast Corridor	4004
Midwest Triangle	4004
Extended-Range Mission	3403

The lower values for the NEC and Midwest Triangle arenas, as compared to the California Corridor, reflect the higher incidence of adverse weather conditions. The extended-range mission value for N. Y. to Chicago is reduced because of scheduling losses caused by the unique combination of longer block times, time-zone changes, and noise curfews.

(2) DOC Equations

The equations used to compute DOC are presented below.

$$DOC = FLCRC + FAOC + HINSC + DPREC + MAINC$$

where

$$FLCRC = [37.51 + 14.534\ (540. \times TOGW \times 10^{-5})^{-3}] \times (BT)$$

$$FAOC = 1.03 \times [(BF)\times(FUELC)+(NE)\times(0.135)\times(OILC)\times(BT)]$$

$$HINSC = [(IR)\times(CT)\times(BT)] \div UTIL$$

$$DPREC = \frac{(M)\times(1 - R)\times(BT)}{(UTIL)\times(DPREP)}$$

where

$$M = CT+(AFSP)\times(CT - TEC)+(ESP)\times(TEC)$$

$$MAINC = SMR \times [(LR)\times(LMHAF+LMHE)\times(1+MBF) +MCAF+MCE]$$

where

$$MCE = (TEC)\times(0.00001)+(FT)\times(TEC)\times(0.00002)$$

$$MCAF = (FT)\times[3+(1.39)\times(CA)]+8+(3.65)\times(CA)$$

$$LMHE = (KFHE)\times(FT)+(KFCE)$$

$$LMHAF = (KFHA)\times(FT)+(KFCA)$$

(3) DOC Terms and Definitions

A listing of variables and their definitions as used in the foregoing DOC equations is presented in this section.

Variable	Definition
AFSP	Airframe spare parts factor
BF	Block fuel in pounds
BT	Block time in hours
CA	Airframe cost $\div 10^6$
CT	Aircraft flyaway cost per aircraft
DOC	Direct operating cost per one-way trip
DPREC	Depreciation cost per trip
DPREP	Depreciation period, years

ENGUC	Engine cost per unit
ESP	Engine spare parts factor
FAOC	Fuel & oil cost
FLCRC	Flight crew cost
FT	Flight time, hours
FUELC	Fuel cost per pound
HINSC	Aircraft hull insurance cost per trip
IR	Insurance rate
KFCA	Maintenance labor manhours (airframe), per cycle
KFCE	Maintenance labor manhours (engines), per cycle
KFHA	Maintenance labor manhours (airframe), per flight hour
KFHE	Maintenance labor manhours (engines), per flight hour
LMHAF	Labor manhours airframe, per trip
LMHE	Labor manhours engine, per trip
LR	Labor rate: dollars per manhour
M	One aircraft & spare parts, total value in dollars
MAINC	Total maintenance cost per trip including STOL adjustment
MCAF	Maintenance material cost (airframe)
MBF	Maintenance burden factor
MCE	Maintenance material cost (engines)
NE	No. of engines per aircraft
OILC	Oil cost per gallon
R	Residual ratio of airframe, engines & spare parts
SMR	STOL maintenance cost ratio
TEC	Total engine cost per aircraft
TOGW	Maximum certified takeoff gross weight, pounds
UTIL	Block hours of aircraft utilization per year per aircraft

(4) Resulting Direct Operating Costs

Direct operating costs as a function of stage length are shown in Figure A-35 for four vehicle sizes.

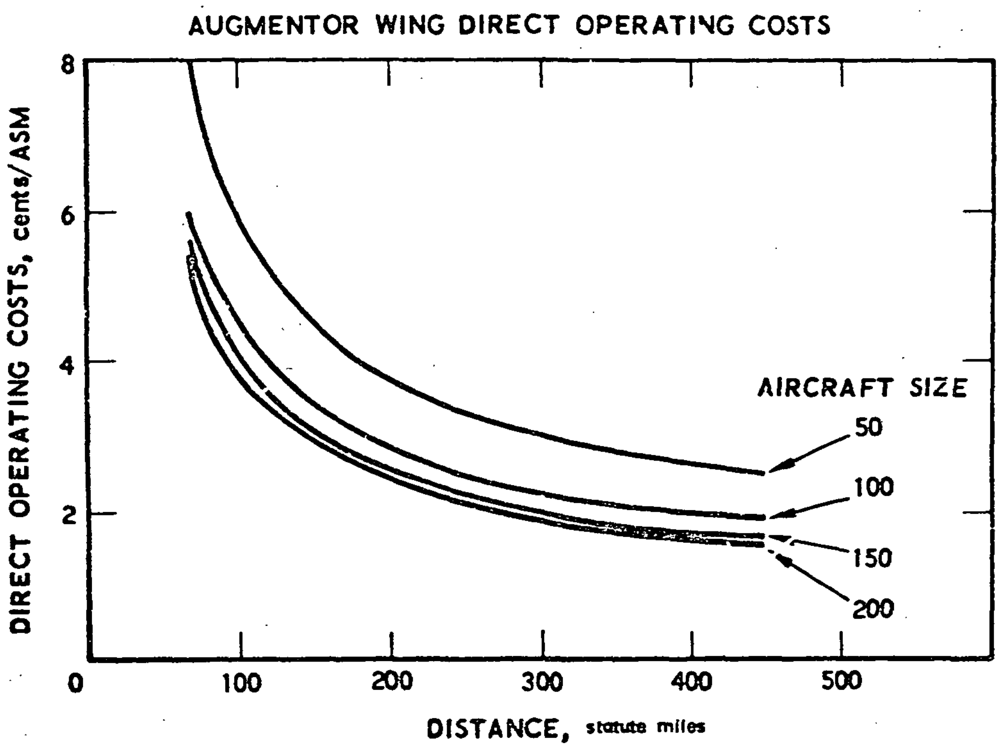


Figure A-35. Augmentor Wing Aircraft, Direct Operating Costs

c. <u>Indirect Operating Costs</u>

(1) California Corridor

The California Corridor indirect operating cost (IOC) model is based on calendar year 1970 PSA cost data (Ref. 31). Each IOC element was examined and allocated in percent to one or more cost items. All IOC elements which are port-related (i.e., dependent on the number and location of ports and level of operations) were combined as an incremental ΔIOC per departure and include landing fees, airport terminal operation, and depreciation of ground property and equipment. The derivation of ΔIOC is included in the next subsection.

The complete IOC per departure is:

$$IOC = \Delta IOC + 0.4385\,(\text{Seat Blk Hr}) + 0.4452\,(\text{No. Pass}) + 0.00248\,(\text{ASM}) + 0.0011\,(\text{RPM})\ 0.02052\,(\text{Pass Rev.})$$

where

ΔIOC	=	Port-related indirect operating costs
Seat Blk Hr	=	Seat block hours
No. Pass.	=	No. of passengers
ASM	=	Available seat miles (statute miles)
RPM	=	Revenue passenger miles (statute miles)
Pass. Rev.	=	Net passenger revenue

The rationale of allocating each IOC element is given in the following subsections.

(a) Passenger Service Expense

Stewardess expense (which includes stewards) accounts for 63 percent of passenger-service expenses and is allocated to seat block hours. Seat block hours are computed for an all-coach configuration. Stewardesses are assigned on the basis of aircraft size (seats) and paid on the basis of hours flown. Thus, seat block hours rather than available seat miles (ASM) or revenue passenger miles (RPM) was the operational item used to allocate stewardess expenses. Passenger food is allocated 50 percent to passengers and 50 percent to RPM to reflect the probable tendency of passengers to eat more on longer flights. The low level of food costs in short-haul service is explained by

- No meal service provided
- Only food (no beverage costs) included, as free beverages are provided out of liquor service profits.

Passenger liability insurance is allocated 100 percent to RPM, since this is the parameter on which the insurance premium rate is established. Other passenger service is composed of items such as interrupted-trip expense,

uniforms, loss, and damages. These items were apportioned to fixed expenses per passenger (65%) and a variable portion (35%) per RPM.

(b) Reservations and Ticket Sales

Passenger ticket sales commissions were allocated 100 percent to net passenger revenue (i.e., passenger revenue exclusive of the ticket tax) since travel agent commissions are based on a percentage of the net passenger fare. Reservations and ticket sales offices were allocated to number of passengers (42%) and to ASM (58%) on the basis that slightly over half of these costs were relatively fixed and that the balance would be sensitive to variations in the volume of traffic.

(c) Advertising and Publicity

This item covers the costs of promoting the use of air transportation and the individual competitive carrier. These costs were allocated to the number of passengers (40%) and ASM (60%), based on the same rationale used for reservations and ticket-office expenses.

(d) General and Administrative

These costs are of a general corporate nature (with the major items being property taxes, accounting, and data processing) and were allocated to ASM (100%), since this is the best general measure of the level of activity. It is to be noted that the PSA cost data include more IOC elements in this classification than do other IOC models such as Boeing (Ref. 32).

Table A-23 summarizes the IOC allocations for the California Corridor. Indirect operating costs are shown in Figure A-36 for four vehicle sizes as a function of stage length.

(2) Northeast Corridor and Midwest Triangle

The data base used to calibrate the IOC model for these two arenas was the calendar 1970 U.S. domestic trunk airlines cost experience (Refs. 32 and 33). This information was combined with the California Corridor IOC results to provide estimates for high-density short haul CTOL or STOL

Table A-23. California Corridor Indirect Operating Cost
Partial Allocation of IOC Per Departure

Item	PSA %	IOC Segment Distribution: Seat Blk Hr	Number of Passengers	Available Seat Miles	Revenue Passenger Miles	Net Passenger Revenue
Passenger Service						
Stewardess Expense	14.07	(100) 14.07				
Passenger Food	0.48		(50) 0.24		(50) 0.24	
Passenger Liability Insurance	5.32				(100) 5.32	
Other Pax Service	2.50		(65) 1.63		(35) 0.87	
Reservations and Ticket Sales						
Passenger Commissions	6.08					(100) 6.08
Reservations and Ticket Off	9.76		(42) 4.10	(58) 5.66		
Advertising and Publicity	8.26		(40) 3.30	(60) 4.96		
General and Administrative	19.30			(100) 19.30		
Port Costs*						
Aircraft and Traffic Service						
Landing Fees	6.85					
Airport Terminal Ops	23.62					
Depreciation (Ground Prop)	3.76					
	100.00	14.07	9.27	29.92	6.43	6.08

From PSA Data: Average Cap = 144.319
Annual IOC = \$24,625,900, IOC/Dep = 306.27
Annual Seat Blk Hrs = 7,900,700, /Dep = 98.29

Average ASM = 36987, Dep/Yr = 80379,
Rev Plane Miles (000) = 20,600 Pass = 5,162,278
Pass. Rev = \$72,949,800 RPM (000) = 1,585,392

Average Load Factor = 53.3%, Average Number Pax = 63.776, Average RPM = 19724

$$\text{Then IOC/Dep} = \frac{306.37}{100}\left[\frac{14.07}{98.29}(\text{Blk Hr} \times \text{CAP}) + \frac{9.27}{63.776}(\text{No. Pax}) + \frac{29.92}{36987}(\text{ASM}) + \frac{6.43}{19724}(\text{RPM} + 0.02052\ (\text{Pass. Rev})\right]$$

$$= \Delta\text{IOC} + 0.4385\ (\text{Blk Hr} \times \text{CAP}) + 0.4452\ (\text{No. Pax}) + 0.00248\ (\text{ASM}) + 0.0011\ (\text{RPM}) + 0.02052\ (\text{Pass. Rev})$$

*Allocated in separate cost models and input as ΔIOC

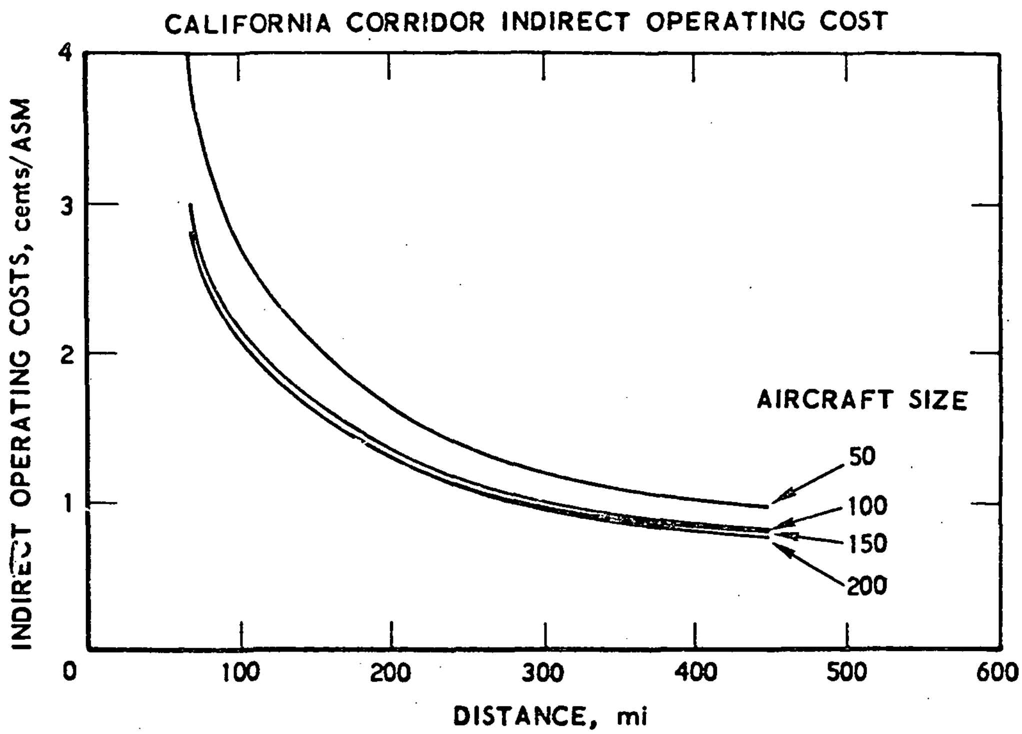


Figure A-36. California Corridor Indirect Operating Costs

service in the NEC/Midwest Triangle arenas. The method and rationale for modification from the 1970 domestic trunk figures to yield the NEC/Midwest Triangle IOC model are shown in Table A-24. The allocation of IOC items is basically the same as in the California Corridor. A comparison of IOC coefficients for common IOC elements is made in Table A-25, where the California Corridor (1970 PSA), 1970 domestic trunk, and the NEC/Midwest Triangle IOC coefficients are displayed. Note the significantly higher cost components of the domestic trunks.

In addition to these common elements, three others were separately identified and allocated for the NEC/Midwest Triangle IOC formulation. These were identified as system costs (independent of the station-operating cost elements accounted for in ΔIOC) and included amortization of preoperating expenses (e.g., startup costs), depreciation of hangars, and aircraft cleaning.

Table A-24. Northeast/Midwest IOC Method and Rationale

High-Density, Short-Haul STOL/CTOL Service

Item and Allocation	Modifications from 1970 Trunk Operations
Stewardess Expense per weighted seat block hour	Reduced parameter value (from \$0.525 to \$0.436) is average of Eastern Airlines (\$0.434) and PSA (\$0.438) and reflects lower crew overnighting expenses on short haul services.
Passenger Food* per weighted passenger and weighted RPM**	Estimated at \$0.00010/RPM + \$0.02/ passenger and reflects elimination of meal service.
Other Passenger Service per RPM and passenger	Cost per RPM is set at \$0.00113, the same as estimated for PSA and the domestic trunks. Reduced value per passenger is \$0.10. Lower proportion of connecting passengers on commuter services results in fewer trip interruptions and therefore lower expenses.
Reservation and Sales per passenger and ASM	Estimated at about PSA cost levels: \$0.200/passenger and \$0.00050/ASM.
Passenger Commissions per net passenger revenue	Average of PSA and domestic trunk percentage.
Advertising and Publicity per passenger and ASM	Average of domestic trunk and PSA parameter values.
General and Administration per ASM	Average of domestic trunks and PSA parameter values.

*Food costs only; complimentary beverage costs are absorbed by liquor service profits.

**Weighting of RPM and Passengers is 1.0 first class = 1.75 coach.

Table A-25. IOC Comparison - Common Elements

IOC Element	Costing Factors	IOC Element in Dollars Per Costing Factor		
		1970 Dom. Trunk	N. E. and Midwest Modified for STOL	1970 PSA
Stewardess	Seat Blk Hr*	0.525	0.436	0.438
Food	50% RPM*	0.00120	0.00010	0.00004
	50% Pass.*	0.938	0.02	0.012
Other Passenger Service	35% RPM	0.00113	0.00113	0.00113
	65% Pass.	0.154	0.10	0.048
Reservations and Sales**	20% Pass.	0.658	0.200	(42%)† 0.195
	80% ASM	0.00172	0.00050	(58%)† 0.00047
Advertising and Publicity	20% Pass.	0.236	0.196	(40%)† 0.157
	80% ASM	0.00060	0.00050	(60%)† 0.00041
General and Administrative	ASM	0.000143	0.00152	0.00160
Passenger Commissions	Pass. Rev ($)	0.0273	0.0234	0.02052
Total Common IOC Elements	Pass.	1.986	0.516	0.412
	RPM	0.00233	0.00123	0.00117
	ASM	0.00375	0.00252	0.00248
	Pass. Rev ($)	0.0273	0.0234	0.02052
	Seat Blk Hr	0.525	0.436	0.438

*All coach service

**Excluding commissions

† Unique costing divisions for PSA

Amortization of preoperating expenses, typically of the promotional nature, was allocated to RPM. Hangar depreciation, a function of the number and size of the aircraft in the fleet, was allocated to ASM. Aircraft cleaning operations, confined to a minority of stations and thus a system cost rather than a station cost, was allocated to ASM. These three additional IOC elements are included in Table A-26, which provides the total listing of IOC allocations for the NEC/Midwest Triangle arenas. The data base for the California Corridor IOC did not separately identify these three IOC elements. Hence, for the California Corridor IOC, these elements are included in the port-related costs, causing the ΔIOC for the NEC/Midwest Triangle to differ from the ΔIOC for the California Corridor for station operating costs.

Indirect operating costs for these two arenas are shown as a function of stage length in Figure A-37 for four vehicle sizes.

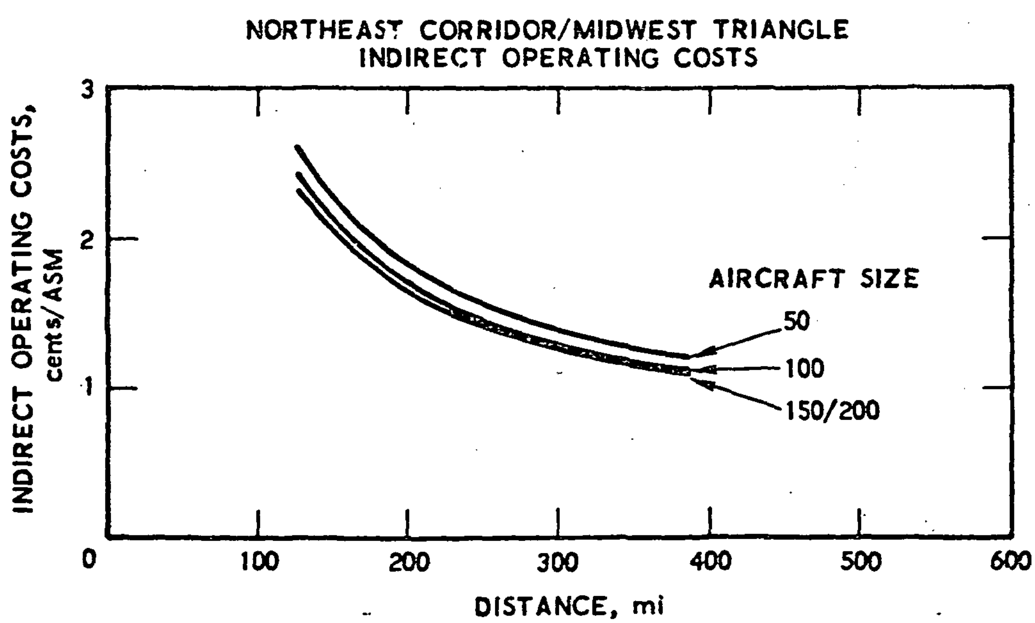


Figure A-37. Northeast Corridor/Midwest Triangle Indirect Operating Costs

Table A-26. Northeast/Midwest Indirect Operating Costs

High-Density, Short-Haul CTOL/STOL Service

(1970 Dollars/Parameter)

Item	No. Passengers[1]	ASM[1]	RPM	Net Passenger Revenue	Seat Blk. Hrs.
Passenger Service					
Stewardess Expense					0.436
Passenger Food	0.020		0.00010		
Other Passenger Service	0.100		0.00113		
Reservation & Sales					
Passenger Commissions				0.0234	
Reservations & Ticketing	0.200	0.00050			
Advertising & Publicity	0.196	0.00050			
General & Administrative		0.00152			
Amortization			0.00024		
Depreciation - Hangars		0.00018			
A/C Cleaning		0.00018			
Port Costs*					
Landing Fees					
Terminal Rents					
Station Operating Costs					
Noise Buffer Zone					
Totals	0.516	0.00278	0.00147	0.0234	0.436

IOC = [0.516 (No. Passengers) + 0.00278 (ASM) + 0.00147 (RPM) + 0.0234 (Net Passenger Revenue) + 0.436 (Seat Blk. Hrs.) + ΔIOC]

*Developed in separate cost models & input as ΔIOC

[1] For all coach operation

d. Port-Related Indirect Operating Costs

Indirect cost models based entirely on CTOL cost experience necessarily reflect system-average IOC levels. The effects of operating from a mix of airports of various sizes and locations with individual user charges, which reflect the costs of existing terminals and airfields, are aggregated into a composite IOC level for the airline. For a STOL system which might operate from entirely new ports or improved general-aviation ports, basing all IOC coefficients on historical CTOL experience would be inaccurate. For these reasons, all IOC elements that are determined by port user charges and port-peculiar operating costs are modeled explicitly and combined as a port-related IOC (ΔIOC) term. That is, STOLport terminals and airfields are costed directly, and the amortized capital and operating expenses are then allocated to the STOL system. The ΔIOC term is the basis for ensuring that the STOL operator eventually absorbs the cost of port facilities required to support the estimated level of STOL operations.

The ΔIOC element accounts for all port-usage charges accruing to the STOL operator. These include three cost elements:

- Airfield and terminal facility use charge (paid as a landing fee or terminal rental by the STOL operator)
- STOL-induced noise buffer zone costs (paid as part of landing fee by the STOL operator)
- Station operating costs (the internal costs to the STOL operator for aircraft and passenger handling at STOL terminals).

The composition of each of these cost elements is examined and its derivation outlined below.

(1) Airfield and Terminal Facility

STOLports are either new ports developed for the exclusive use of the STOL system, existing air carriers, or general-aviation airports to be used by the STOL service. In the case of new STOLports (e.g., Patton Field in Los Angeles) the land acquisition, site preparation, and airfield construction costs are developed and combined as the capital cost of the

airfield. For existing airports with operational runways of sufficient length and thickness, only a landing fee rate was charged (e.g., Boston Logan landing fee for STOL was $0.3367 per 1000 pounds of gross landing weight).

The airfield costs are a function of the runway and taxiway pavement-overlay needed. Required runway thickness was determined on the basis of FAA runway standards for dual-tandem landing gear aircraft (Ref. 34). The thickness of the existing runway was subtracted from the required thickness to determine the thickness-augmentation needed. This was done for each STOL vehicle capacity; i.e., weight, at each STOLport. A standard STOL runway 2000 feet long and 100 feet wide with a 60-foot wide taxiway was used to determine the total cubic feet of required paving. A paving unit cost of $0.677 per cubic foot was used (Ref. 35). The STOL system was charged only for the airfield improvements required to support STOL operations.

The terminal-building floor area requirements are a function of peak-hour passengers. The floor area per peak-hour passenger figure was adjusted for STOL operations (Ref. 35). The cost per square foot was $36.25 for all terminals except Secaucus, where local authorities supplied a figure of $45.30 per square foot. In a situation where a small number of operations occur per day, the determining factor in terminal size becomes the minimum-size terminal capable of handling one aircraft operation. For this reason, the cost basis for STOL terminals involved either a basic minimum terminal of $435,000, or $2,900 per peak-hour passenger, whichever was larger. The required apron paving was also costed on the basis of the number of aircraft gates required. In the case of new STOLports, land acquisition and site preparation costs included the area needed for terminal concessions and access roads.

In addition to the amortized capital costs, the STOL operator was charged the maintenance and operating costs of the STOLport facilities. The cost functions for airfield and terminal operating costs were derived from linear-regression fits of airport expenses taken from The Aerospace Corporation Airport Revenue and Expense Model. This model contains

cross-sectional revenue and expense data for 160 air-carrier and general-aviation airports. The expense data used for terminal and airfield operating costs included allocated general and administrative costs. The resulting annual cost functions in 1970 dollars were:

$$\text{Airfield operating costs (\$/year)} = 38055\ (NP) + 2.542\ (ND) + 0.009508\ (ND)\left(\frac{GTOW}{1000}\right)$$

where:

NP = No. of STOLports
ND = No. of annual departures from all STOLports
GTOW = Aircraft gross takeoff weight - lb

$$\text{Terminal Operating Costs (\$/year)} = 0.2727\ (ANP)$$

where:

ANP = Annual no. of enplaning STOL passengers

(2) Noise Buffer Zone

The impact of noise on the economics of a STOL operation can be assessed by computing noise buffer zone costs for each STOLport as a function of aircraft size and level of operations and assigning the applicable costs to the operator in landing fees. The cost of acquiring noise-impacted land parcels is calculated for each land zone impacted. In addition to the basic market value of the impacted land, acquisition costs include project overhead, resident relocation, and rehousing costs for all impacted land zones.

The capital costs for airfield, terminal, and noise buffer zone are amortized by a straight-line depreciation to a zero residual over an expected economic life of 25 years. The interest costs are approximated by an annual amount equal to the interest rate times the average value. Given the depreciation to a zero residual, the average value over the life of the project equals one-half of the capital cost. The interest rate chosen (6%) assumes a tax-free municipal funding agency.

(3) Station Operating Costs

The costs incurred by the STOL operator in terminal operations were developed separately for the California Corridor and the NEC/Midwest Triangle arenas. For the California Corridor, the 1970 PSA data base (Ref. 31) was used, resulting in the following equation:

$$\text{Station Operating Costs (\$/year)} = 26,100\ (NP) + 8.55\ (ND) + 0.173\ (ND)\ (GTOW) + 0.496\ (ANP) + 39.37\ (TEB)$$

where

TEB = annual tons of enplaning baggage = 0.00353 (ANP)

The derived cost functions covered the combined IOC categories of aircraft control, aircraft handling, passenger handling, baggage handling, and ground property depreciation and maintenance. Landing fees and terminal rentals, which were explicitly derived for STOL operations, were excluded from the data.

For the Northeast Corridor/Midwest Triangle arenas, detailed United Airlines station operating cost data were obtained for a representative sample of 24 stations. These data plus additional Western Airlines data permitted isolation of the indirect cost categories of aircraft handling, passenger handling, ground property and equipment depreciation, maintenance expense, and the separation of baggage from cargo handling expenses. The following equation resulted:

$$\text{Station Operating Costs (\$/year)} = -166,290\ (NP) + 7.38\ (ND) + 0.3912\ (ND)\ (GTOW) + 1.51\ (ANP) + 48.94\ (TEB) + 0.0001645\ (TEB)^2 - 6.876\ (ANP)^{2.5}\ (10)^{-11}$$

A minimum annual station operating cost of $60,000 was used. This figure is also used by the Civil Aeronautics Board (CAB) as an allowable expense-per-station for stations of more than one round trip per day (Ref. 36).

Cost coefficients for California Corridor stations are generally significantly lower than those for NEC/Midwest Triangle stations. Part of the reason is that items allocated to station-operating costs in the United Airlines data are classified as a general and administrative expense in the PSA California Corridor data. In addition, trunk airlines' operating in medium- and long-haul markets share the same terminal facilities with short-haul airlines operating in high-density markets. This probably leads to a requirement for facilities which, for short-haul commuter services, are excessive in size and quality. The existence of numerous fares and dual-class service in interstate markets leads to a requirement for additional passenger-handling personnel. By contrast, stewardesses on intrastate commuter services act as ticket collectors. Available data did not permit a detailed examination of the exact reason for the differences in station operating-cost levels between intrastate California Corridor operations and those experienced by United Airlines. Therefore, it was decided to model the California Corridor STOL system and the NEC/Midwest Triangle STOL systems station operating costs separately with each relating to the appropriate data base.

e. Total Operating Costs

A representative example of total operating costs for four STOL service paths is presented in Table A-27. Two are from the California Corridor and involve a lower IOC level than the two service paths from the NEC/Midwest Triangle Arenas.

f. Return on Investment

Return on investment (ROI) measures the profitability of a business in relationship to the amount of capital being placed at risk. It is one of many measures used by investors and businesses to evaluate alternative uses of capital. Airline operators are subject to regulation by either the Civil Aeronautics Board (CAB) in the case of interstate carriers or a state Public Utilities Commission (PUC) in the case of an intrastate carrier. One aspect of the regulations is designed to prevent excessive profits on the part

Table A-27. STOL Operating Costs

150-Passenger Augmentor Wing

City Pair/Service Path	Distance (St. Mi.)	Block Time (hr)	Utilization Annual Hr	Load Factor	DOC /Trip	DOC /ASM	IOC /Trip	IOC /ASM	Total Operating Cost /Trip	Total Operating Cost /ASM
California Corridor										
LA - SF										
Patton - India Basin	347	.93	3010	65%	$949	$.0162	$468	$.0090	$1417	$.027
LA - San Diego										
Patton - Montgomery	101	.46	2360	65%	$613	$.0405	$308	$.0204	$ 921	$.060
NEC/Midwest										
Detroit - Cleveland										
Det. City - Burke	92	.44	2249	65%	$601	$.0436	$405	$.0293	$1006	$.0729
Boston - Philadelphia										
Logan - N. Phl.	260	.76	2760	65%	$539	$.0215	$541	$.0139	$1380	$.0354

DCC Direct Operating Cost

IOC Indirect Operating Cost

ASM Available Seat Mile (statute miles)

of the carriers; consequently, the regulatory agencies specify both the method of calculating ROI as well as reasonable limits on the maximum rate of return permitted.

The CAB computes ROI as the ratio of interest and net profit to the investment base. The size of the interest payment is dependent on the debt/equity ratio of the airline and the interest rate. Five investment categories are specified:

- Total long term debt
- Convertible debentures
- Commou stockholder equity
- Preferred stock equity
- Retained earnings.

The California Corridor market is regulated by the California PUC, which computes ROI as the ratio of net profit to investment base. Thus, an airline with borrowed funds in its investment base will produce an ROI by the CAB formula that is greater than that computed by the PUC formula by the rate of interest times the level of debt financing.

For the interest rate (7%) and the debt/equity ratio (75%/25%) used in this study, the CAB ROI is 5.25-percent higher than the corresponding Calif. PUC ROI. As is shown in Table A-28, the CAB 8-percent ROI is equivalent to a 2.75-percent Calif. PUC return on investment, and in addition, equals an 11-percent return on stockholder equity. Interest in the CAB 8-percent ROI is heightened by recognition of the fact that this level approximates the 10.4-percent average return on stockholder equity experienced in the U.S. economy for the time period 1969/71 (Ref. 37). CAB zero-percent ROI represents the case where the size of the net loss incurred by the airline equals its interest payments. It is viable only when the provider of borrowed funds is willing to accept a zero return. At the CAB ROI = 5.25%, net income equals zero; i.e., operating income is just sufficient to cover interest payments. The next two ROI values listed in Table A-28 represent the approximate range of maximum ROI permitted by the regulatory bodies.

Table A-28. ROI Equivalence

CAB % ROI	California PUC % ROI	Return on Stockholder Equity
0	-5.25	-21.0
5.25	0	0
8.0	2.75	11.0
12.0[a]	6.75	27.0
12.5[b]	7.25	29.0

[a] Applied only in Midwest Triangle and NEC Analyses
[b] Applied only in Calif Corridor Analysis

Their correspondence to high levels of return on equity may indicate why the airline industry, with its high debt/equity ratios, does not achieve an average ROI as great as that allowed by the regulatory agencies.

In practice, application of the CAB formula requires detailed financial data that are usually not available for systems studies. Therefore, an ROI method was developed for this study which incorporates such parameters as original aircraft cost, spares and flight equipment, average value of flight equipment, other asset factors, average debt/liability ratio, interest rate, and tax rate.

The STOL investment base was established from an analysis of the investment base of all certified air carriers (Ref. 30). It was found that the ratio of net value of flight equipment to original cost was 0.678. This factor, called ratio of book value, is applied to the flight equipment investment. The factor for investment in ground property and equipment (which varies by arena) is also applied to the flight equipment investment. The application of these two factors produces a net investment base which includes ground facilities and which reflects the deduction of accrued depreciation. Analysis of the certified air carrier investment base also yielded a 73.4-percent ratio of debt to total investment, which was rounded off to 75 percent for purposes of this study. An interest rate of 7 percent and an average effective corporate income tax rate of 40 percent were also used in calculating ROI for the 1980 STOL system.

Based on the estimated debt to total investment ratio and interest rate, the resulting ROI equation was:

$$ROI = a_1 + \frac{a_2 \times PROFIT}{TOTINV}$$

where

ROI	=	Annual rate of return on investment
PROFIT	=	Average daily STOL system profit
TOTINV	=	Total investment - gross value before accrued depreciation
a_1	=	0.021
a_2	=	323

VOLUME II

APPENDIX B

ARENA CHARACTERIZATION

CONTENTS

		Page No.
B.1	Arena and Regional Definitions	B-1
B.2	Regional Traveler Characteristics	B-1
B.3	City Characteristics	B-10
	a. Demographic Characteristics	B-10
	b. Intercity Transportation Port Characteristics	B-19
	c. Local Transportation Characteristics	B-25
B.4	Intercity Travel Characteristics	B-35
	a. Data Base Development	B-39
	b. Total Travel Demand Projections	B-43
	c. Projected Service Characteristics	B-48
B.5	Data Sources	B-60
	a. California Corridor	B-60
	b. Midwest Triangle	B-61
	c. Northeast Corridor	B-63

FIGURES

B-1.	California Corridor	B-2
B-2.	Midwest Triangle	B-3
B-3.	Northeast Corridor	B-4
B-4.	Los Angeles Region	B-13
B-5.	Los Angeles Stylized Zones	B-14
B-6.	San Francisco Superzones	B-27
B-7.	New York Superzones	B-29
B-8.	Philadelphia Superzones	B-30
B-9.	Boston Superzones	B-31
B-10.	Washington, D. C. Superzones	B-33
B-11.	Travel Demand Calibration Data Base	B-45
B-12.	Correlation between Rate of Change of Log Travel Demand and Level of Demand	B-46
B-13.	Intercity Travel Demand Model	B-47

TABLES

		Page No.
B-1.	Arena and Regional Demographic Characteristics	B-5
B-2.	California Corridor Traveler Characteristics	B-7
B-3.	Midwest Triangle Traveler Characteristics	B-8
B-4.	Northeast Corridor Traveler Characteristics	B-9
B-5.	Regional Zonal Data Sources	B-12
B-6.	Sample Zonal Characteristics, Los Angeles	B-16
B-7.	California Corridor Port Characteristics	B-21
B-8.	Midwest Triangle Port Characteristics	B-22
B-9.	Northeast Corridor Port Characteristics	B-23
B-10.	Average Auto Speeds for a 5-Mile Local Trip	B-34
B-11.	San Francisco Intersuperzone Penalties	B-36
B-12.	New York Intersuperzone Penalties	B-37
B-13.	Philadelphia Intersuperzone Penalties	B-38
B-14.	Boston Intersuperzone Penalties	B-38
B-15.	Washington, D.C. Intersuperzone Penalties	B-39
B-16.	California Corridor and Midwest Triangle Modal Demand	B-41
B-17.	Northeast Corridor Modal Demand	B-42
B-18.	Variation between Actual and Estimated Intercity Annual Two-Way Traffic within the California Corridor, 1960	B-44
B-19.	Total Intercity Travel Demand Forecasts	B-49
B-20.	California Service Path Characteristics	B-50
B-21.	Midwest Triangle Service Path Characteristics	B-53
B-22.	Northeast Corridor Service Path Characteristics	B-54

APPENDIX B

ARENA CHARACTERIZATION

B.1 ARENA AND REGIONAL DEFINITIONS

Specific regions in each arena were defined to permit analysis of the intercity modal travel demand. The boundaries of these regions were chosen to include all existing major transportation ports as well as large centers of population and employment. Another factor which dominated the choice of these boundaries was the availability of zonal data on population, income, and travel demand. Each of the cities included in the California, Midwest, and Northeast arenas is under the jurisdiction of regional planning agencies. These organizations have defined regional and zonal boundaries that were used directly in this study. In the California and Midwest arenas, the entire regions defined by these agencies were used. In the Northeast Corridor (NEC), those portions of the New York and Washington, D.C. regions having extremely low population densities were deleted.

Figures B-1 through B-3 show the regions defined in the study. The California Corridor, in Figure B-1, consisted of Los Angeles, Sacramento, San Diego, and San Francisco. The Midwest Triangle in Figure B-2 included Chicago, Cleveland, and Detroit. The Northeast Corridor, in Figure B-3, consisted of Boston, New York, Philadelphia, and Washington, D.C. A summary of arena and regional demographic characteristics is presented in Table B-1.

B.2 REGIONAL TRAVELER CHARACTERISTICS

In the California Corridor, individual trip frequency as a function of income, trip purpose, and trip distance was obtained from the 1967 Census of Transportation (CT) Data Tape for SMSA-SMSA* travel within California. For this corridor, city pairs were grouped into long distances (250 to 600 miles) and short distances (50 to 249 miles). Thus, Los Angeles

*Standard Metropolitan Statistical Area

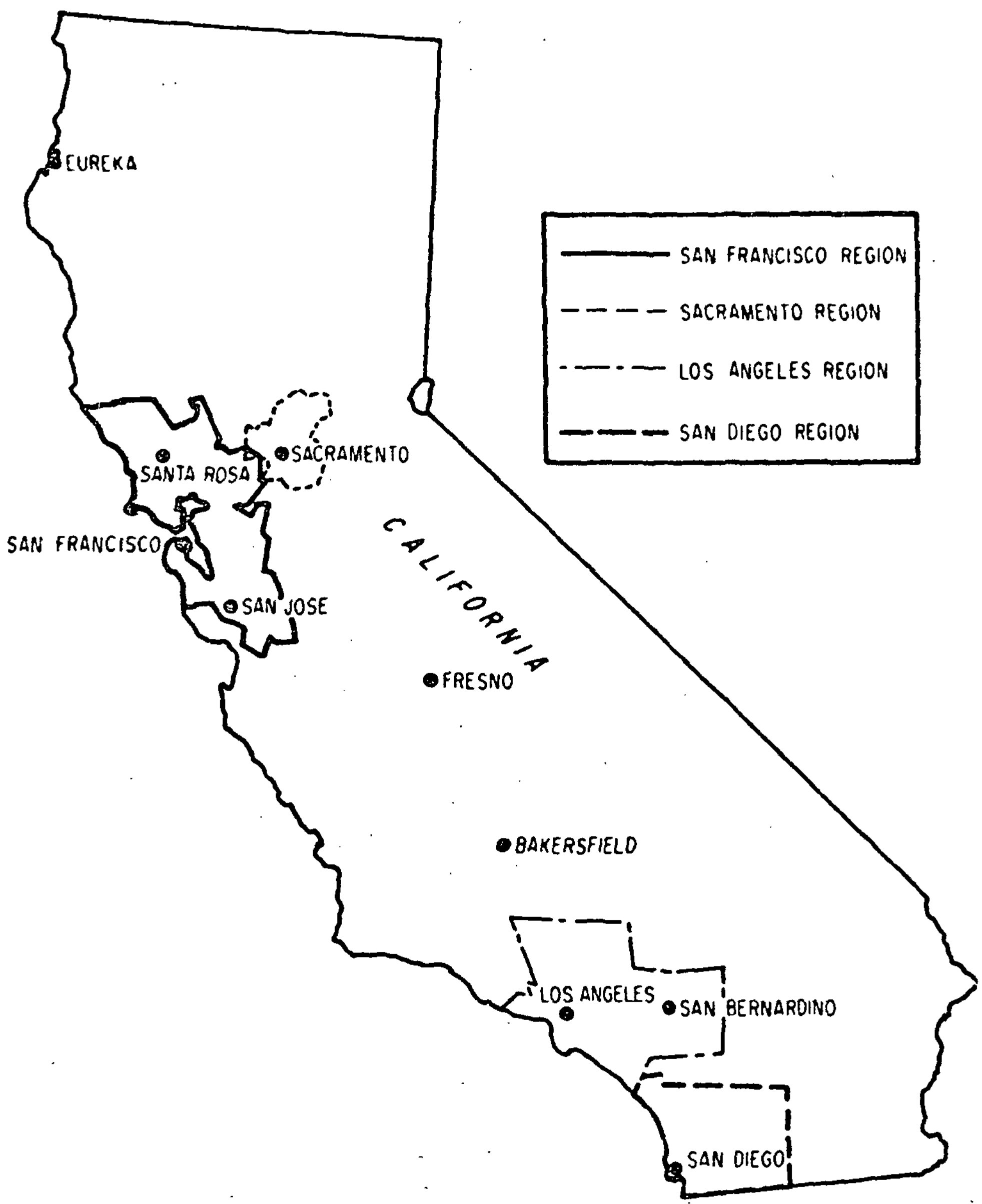


Figure B-1. California Corridor

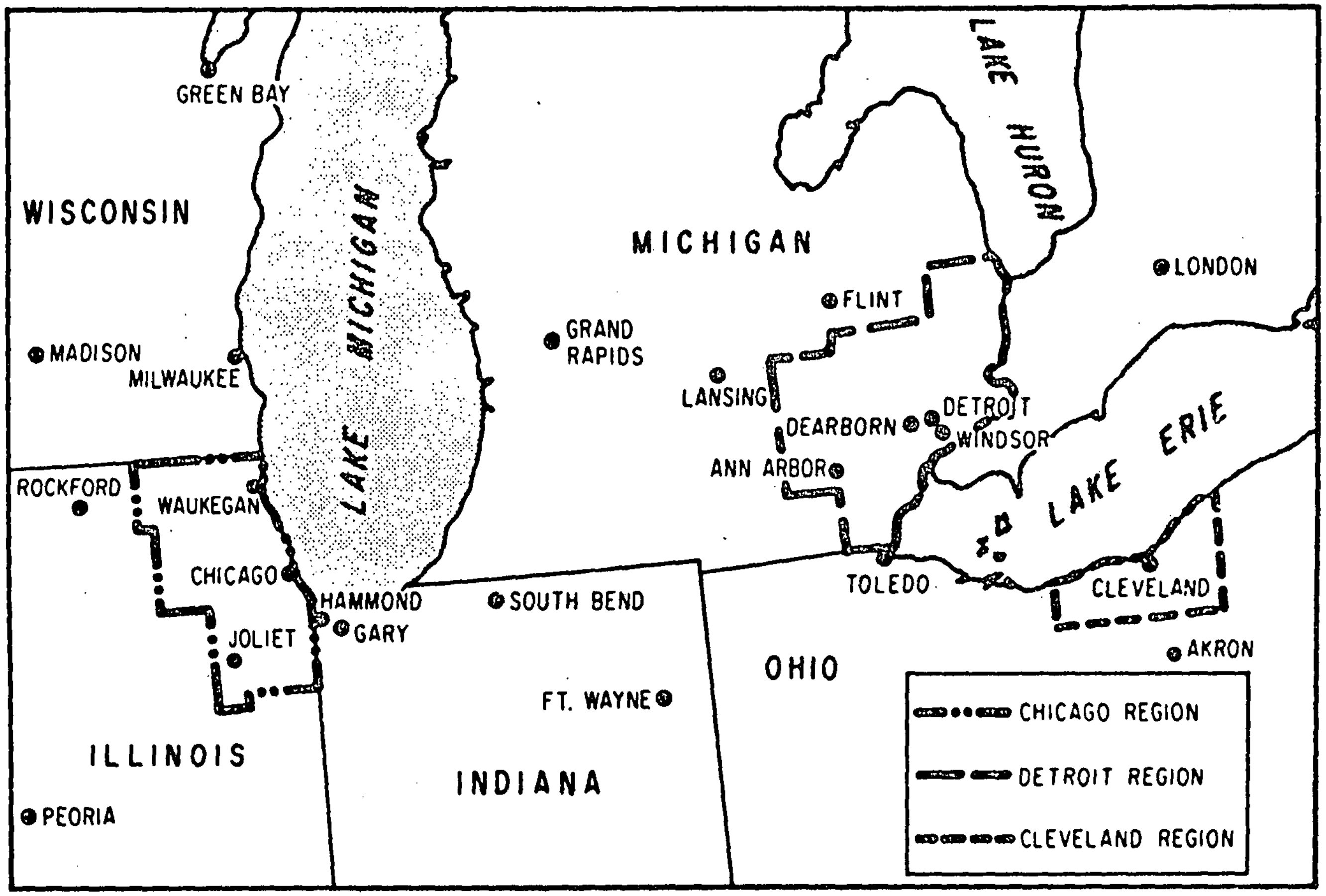


Figure B-2. Midwest Triangle

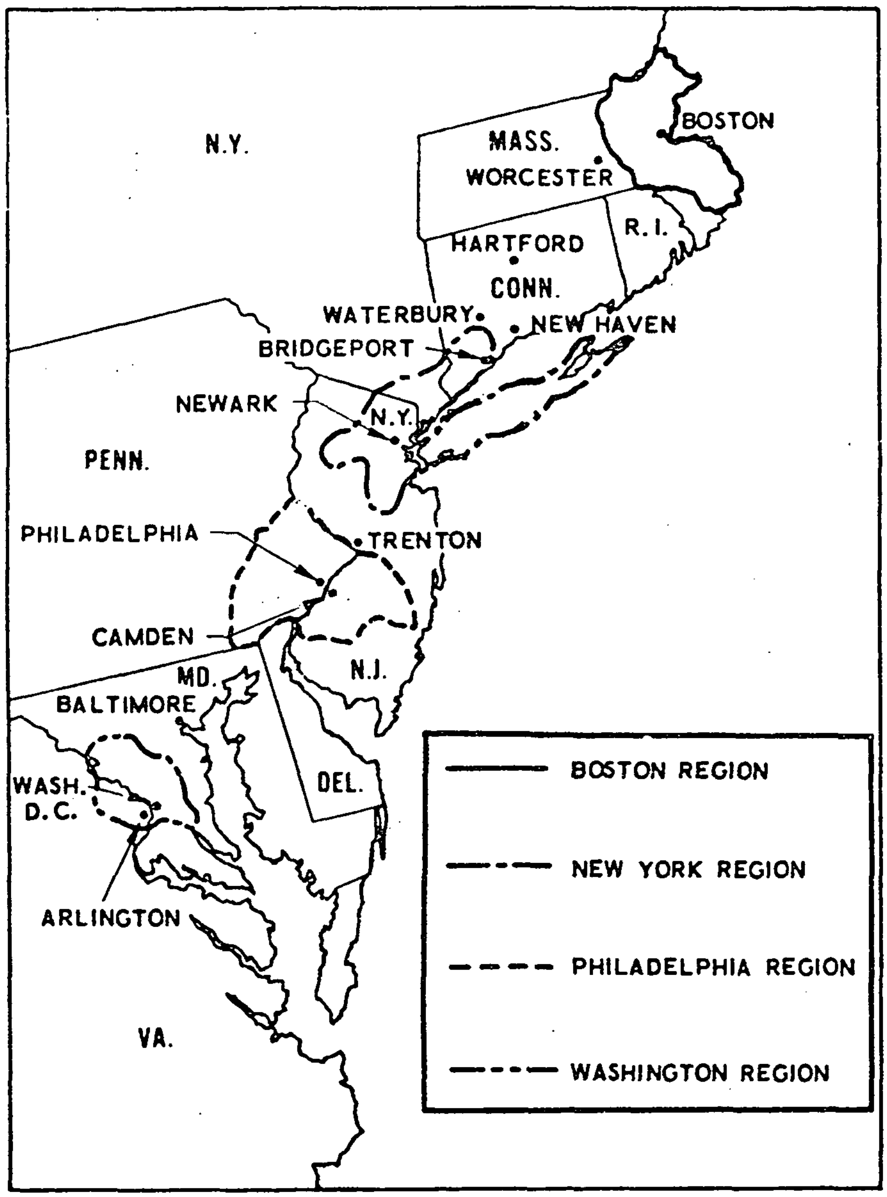


Figure B-3. Northeast Corridor

Table B-1. Arena and Regional Demographic Characteristics

Arena	Region	Stylized Area (mi^2)	Population		1980 Population Density ($pers/mi^2$)	Median Income		Hotel/Motel Units
			1967	1980		1967	1980	
California Corridor	Los Angeles	6160	9,193,254	11,183,489	1816	7756	9658	32,473
	Sacramento	1960	756,103	1,015,503	518	7870	13857	3,687
	San Diego	2660	1,200,295	1,755,260	660	7608	16321	24,370
	San Francisco	6520	4,250,367	5,322,169	816	9224	12146	26,486
		17,300	15,400,019	19,276,421	1114	8155	11173	87,016
Midwest Triangle	Chicago	3450	6,878,671	8,705,530	2523	10809	15586	111,002
	Cleveland	1380	2,184,057	2,552,525	1850	9469	14745	9,573
	Detroit	3790	4,536,205	5,779,050	1525	8964	14692	15,891
		8020	13,598,933	17,037,105	1976	9978	16681	136,766
			1968			1968		
Northeast Corridor	Boston	2513	3,804,250	4,206,900	1674	9555	15413	11,263
	New York	3138	17,180,400	20,049,100	6389	8957	13065	59,011
	Philadelphia	3521	4,310,206	4,700,000	1335	8152	11414	13,424
	Wash., D.C.	1621	2,570,300	3,857,300	2380	10961	18039	32,961
		10,793	27,865,156	32,813,300	3040	9122	13714	116,659

or San Diego to either San Francisco or Sacramento were considered long distance city pairs, and Los Angeles to San Diego and San Francisco to Sacramento were categorized as short distance city pairs. Distributions of trips by purpose, duration, and party size were also extracted from the 1967 CT Data Tapes. The California Corridor traveler characteristics for the two distance regimes are shown in Table B-2. In the Midwest Triangle, travel frequency and traveler characteristics data were also obtained from the 1967 Data Tape. Traveler statistics from Indiana and Wisconsin were added to those of Illinois, Michigan, and Ohio in order to obtain an acceptable sample size. The Midwest Triangle city pairs were grouped into long distances (200 to 400 miles) and short distances (75 to 199 miles). Thus, Chicago to Cleveland and Chicago to Detroit were defined as long distance city pairs and Detroit to Cleveland as a short distance city pair. Traveler characteristics for these sets are shown in Table B-3.

In the NEC, the trip frequency data were obtained from the Census of Transportation Tape for the eight-state Northeast region. Party size and trip-duration characteristics were derived from data presented in Ref. 38. These data were available on a city-pair basis stratified by trip purpose for all city-pairs except Boston-Philadelphia. Data for this city pair were derived from a weighted average of Boston to Washington and Boston to New York data. The weighting factors were 0.585 for Boston to New York and 0.415 for Boston to Washington. These weighting factors are based upon the differences in city-pair distances relative to the Philadelphia-to-Boston distance since, for a given arena and trip purpose, distance is the dominant factor influencing trip duration and party size. Results for all NEC city pairs are shown in Table B-4.

An additional piece of data obtained from the Census of Transportation tape is the hotel factor. This is the fraction of nonbusiness travelers staying in commercial lodging in the nonresident city. It is used to distribute nonbusiness, nonresident demand between residential areas and areas having a concentration of commercial lodging establishments.

Table B-2. California Corridor Traveler Characteristics

Short Trip Characteristics

(LA-SD, SF-SAC)

- Trip Purpose Probabilities:

  Business - 16.75%

  Nonbusiness - 83.25%

- Party Size Distributions:

Party Size	Probability: Business	Probability: Nonbusiness
1	66.9%	13.8%
2	24.0%	33.8%
3	3.5%	14.2%
4	3.1%	16.1%
5	1.9%	13.9%
6+	0.6%	8.2%

- Trip Duration Distribution (Lognormal):

  Business - 1.0 Days (Median)

  2.8 (Standard Deviation)[1]

  Nonbusiness - 1.34 Days (Median)

  2.9 (Standard Deviation)

Long Trip Characteristics

(LA-SF, LA-SAC, SF-SD, SAC-SD)

- Trip Purpose Probabilities:

  Business - 29.1%

  Nonbusiness - 70.9%

- Party Size Distributions:

Party Size	Probability: Business	Probability: Nonbusiness
1	75.1%	22.1%
2	11.8%	32.6%
3	4.0%	10.2%
4	5.4%	12.1%
5	2.3%	12.3%
6+	1.4%	10.8%

- Trip Duration Distribution (Lognormal):

  Business - 1.35 Days (Median)

  3.1 (Standard Deviation)

  Nonbusiness - 3.0 Days (Median)

  2.9 (Standard Deviation)

- Hotel Factor = 9.371

[1] Standard deviation is a multiplicative factor and is dimensionless; e.g., the plus-one sigma for the lower right-hand case is 3.0 days × 2.9 = 8.7 days; the minus-one sigma value is 3.0 days ÷ 2.9 = 1.03 days.

Table B-3. Midwest Triangle Traveler Characteristics

- **Short Trip Characteristics**

  (DET-CLEV)

  Trip Purpose Probabilities:

  Business - 31.0%
  Nonbusiness - 69.0%

- Party Size Distributions:

Party Size	Probability: Business	Probability: Nonbusiness
1	76.7%	20.5%
2	12.0%	33.2%
3	4.9%	14.7%
4	2.5%	12.0%
5	1.4%	6.5%
6+	2.5%	12.2%

- Trip Duration Distribution (Lognormal):

  Business - .65 Days (Median)
  3.3 Days (Standard Deviation)
  Nonbusiness - 1.0 Days (Median)
  2.6 Days (Standard Deviation)

Long Trip Characteristics

(CHIC-CLEV CHIC-DET)

- Trip Purpose Probabilities:

  Business - 31.9%
  Nonbusiness - 68.1%

- Party Size Distributions:

Party Size	Probability: Business	Probability: Nonbusiness
1	76.4%	26.9%
2	11.0%	28.8%
3	4.1%	17.0%
4	5.4%	13.1%
5	1.4%	5.5%
6+	1.7%	8.7%

- Trip Duration Distribution (Lognormal):

  Business - 1.75 Days (Median)
  2.7 Days (Standard Deviation)
  Nonbusiness - 2.4 Days (Median)
  2.4 Days (Standard Deviation)

- Hotel Factor = 0.191

[1] Standard deviation is a multiplicative factor and is dimensionless; e.g., the plus-one sigma for the lower right-hand case is 2.4 days × 2.4 = 5.76 days; the minus-one sigma value is 2.4 days ÷ 2.4 = 1.0 day.

Table B-4. Northeast Corridor Traveler Characteristics

	NY-WASH	NY-BOS	WASH-BOS	WASH-PHIL	BOS-PHIL
• Trip Purpose (%)					
Business	37.0	36.0	42.6	34.8	38.8
Nonbusiness	63.0	64.0	57.4	65.2	61.2
• Party Size Distribution (%)					
Party Size			(Business/Nonbusiness)		
1	54.2/27.7	51.6/26.5	57.2/41.4	50.1/21.9	53.9/32.7
2	27.8/32.2	31.3/35.7	28.8/31.4	29.6/32.0	30.2/33.9
3	8.4/14.8	8.8/16.1	4.4/13.0	7.5/14.7	7.0/14.8
4	5.4/14.6	5.8/12.3	6.0/8.0	8.0/15.4	5.9/10.5
5	2.6/6.5	1.8/5.4	2.3/4.3	1.5/10.0	2.0/5.0
6+	1.6/4.2	0.7/4.0	1.3/1.9	3.3/6.0	1.0/3.1
• Trip Duration Distribution (Days)					
Business					
Median	1.06	0.94	1.22	0.90	1.06
Standard Deviation[1]	3.4	3.3	3.4	2.9	3.3
Nonbusiness					
Median	1.42	1.21	1.98	0.9	1.53
Standard Deviation	2.4	2.8	2.5	2.7	2.7
• Hotel Factor = 0.200					

[1]Standard deviation is a multiplicative factor and is dimensionless; e.g., the plus-one sigma for the lower right-hand case is 1.53 days × 2.7 = 4.13 days; the minus-one sigma value is 1.53 days ÷ 2.7 = 0.57 day.

Within any arena, certain general relationships can be found among traveler characteristics. The fractions of business trips and trip duration generally increase with the city-pair distance, while party sizes decrease. For a given city-pair distance, business trips are of shorter duration than nonbusiness trips, and business party sizes are generally smaller than nonbusiness party sizes. Looking across arenas it can be seen that, for a given city-pair distance, the fraction of business trips is largest in the Northeast and smallest in California. It also appears that trip durations are generally longer in California than in the Northeast for both business and nonbusiness travel. The large hotel factor in California might be attributed to the large influx into the state of people who are without friends and relatives with whom they can stay and the large amount of car travel that makes less-expensive suburban motels an attractive source of lodging. The small value for the Midwest Triangle may be due to the well-established family roots existing in that area.

B.3 CITY CHARACTERISTICS

The scaled maps in all odd-numbered figures in Appendix D, as well as Figures 11 through 21 of Volume I (Ref. 39), identify the boundaries of each region considered in the study. In addition to state and county boundaries, they include the designation and location of ports for each of the non-STOL travel modes as well as the candidate STOLport locations.

a. Demographic Characteristics

In order to spatially distribute travel demand within each region, a data base had to be developed giving zonal data on residential population and income, workplace population and income, and the number of hotel/motel accomodations. In addition, 1980 projections of these variables were

required to allow estimation of future zonal travel demand distributions. Data for this task were obtained by visiting numerous agencies in each arena including city, county, and regional planning agencies as well as convention bureaus and state finance agencies.

The specific agencies supplying the zonal data are listed in Table B-5. In some cases, the regions used multiple systems of zone divisions. The particular zonal system chosen depended on the additional accuracy to be gained by subdividing the city into a large number of zones compared to the aggregation and computational work required to obtain and process the associated inputs to the modal split simulation model. To facilitate storage and handling in the computer, each regional zone was stylized as closely as possible by rectangles. This process left voids in areas of extremely low or zero-population density (mountains, deserts, bodies of water). In a few cases, zones were fitted with more than one rectangle to improve the accuracy of the representation. An example of the stylization process is shown in Figures B-4 and B-5. Figure B-4 shows the LARTS zoning for the five counties comprising the Los Angeles region, and Figure B-5 shows the rectangularization required for computer input. The development of specific data for each of these zones will be discussed in the ensuing paragraphs.

(1) Population

Population data were generally available from home surveys conducted by the local regional planning agency. In some cases, these were on a minor zone basis and had to be aggregated to obtain major zone values. Since the 1970 Census totals were available, the survey results were controlled to these totals. Planning agency projections were also used for developing the 1980 zonal populations and controlled to county projection totals.

(2) Residential Income

Minor zone income statistics from regional home survey data were combined with population data to obtain a weighted median income for major zones.

Table B-5. Regional Zonal Data Sources

Corridor	Region	Regional Organization Data Source	Base Data Zone Nomenclature	Number of Stylized Zones
California	Los Angeles	Los Angeles Regional Transportation Study (LARTS)	LARTS Statistical Areas	96
	Sacramento	Sacramento Area Transportation Study (SATS)	Regional Analysis Districts (RADS)	32
	San Diego	San Diego Metropolitan Area Transportation Study (SDMATS)	Subregional Areas	42
	San Francisco	Bay Area Transportation Study Commission (BATSC)	Districts (BASAR Zones)	99
Midwest	Chicago	Chicago Area Transportation Study (CATS)	Range-Township Areas	96
	Cleveland	Northeast Ohio Areawide Coordinating Agency (NOACA)	Planning Districts	70
	Detroit	Detroit Regional Transportation and Land Use Study (TALUS)	Analysis Superdistricts	55
Northeast	Boston	Boston Transportation Planning Review (BTPR)	BTPR Districts	96
	New York	Tri-State Regional Planning Commission	Data Aggregation Districts & Zones (DADZ)	91
	Philadelphia	Delaware Valley Regional Planning Commission (DVRPC)	Data Collection Districts (DCD's)	85
	Wash., D.C.	Metropolitan Washington Council of Governments	Policy Analysis Districts	93

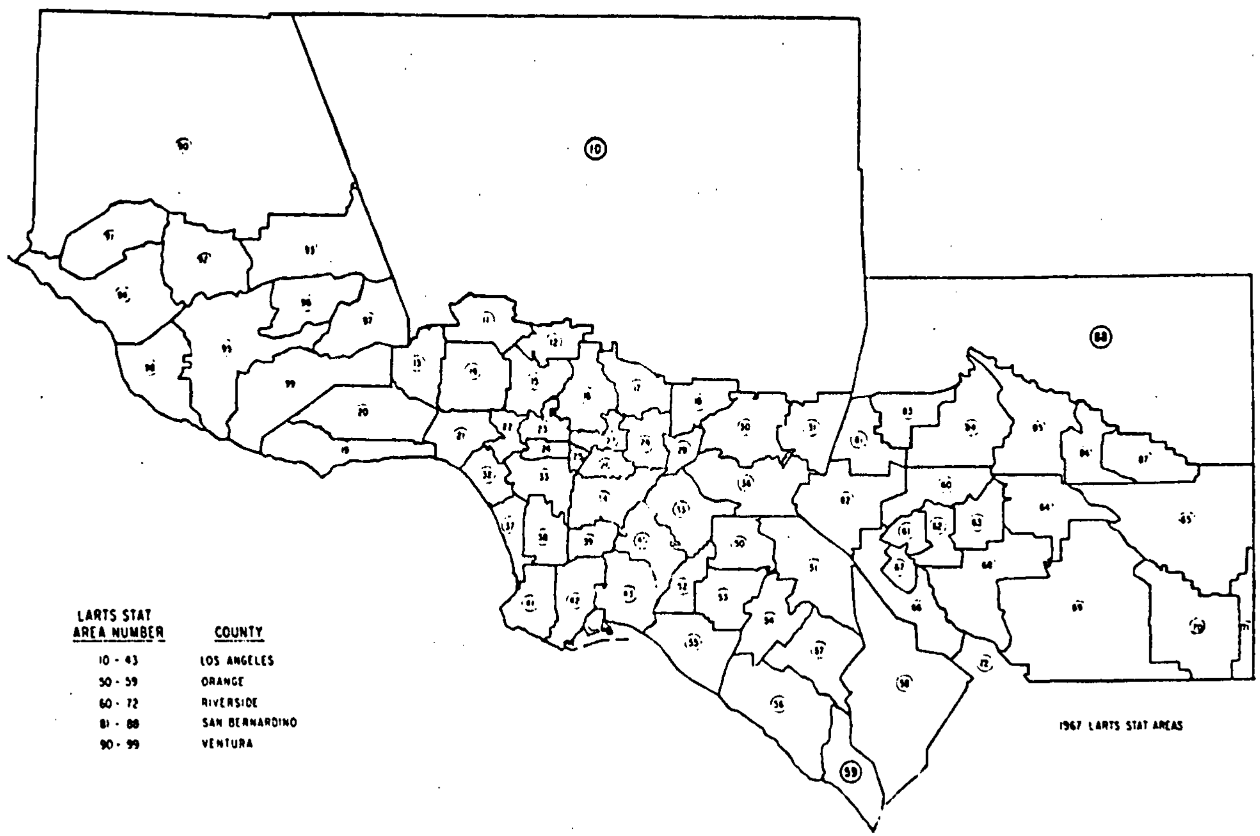


Figure B-4. Los Angeles Region

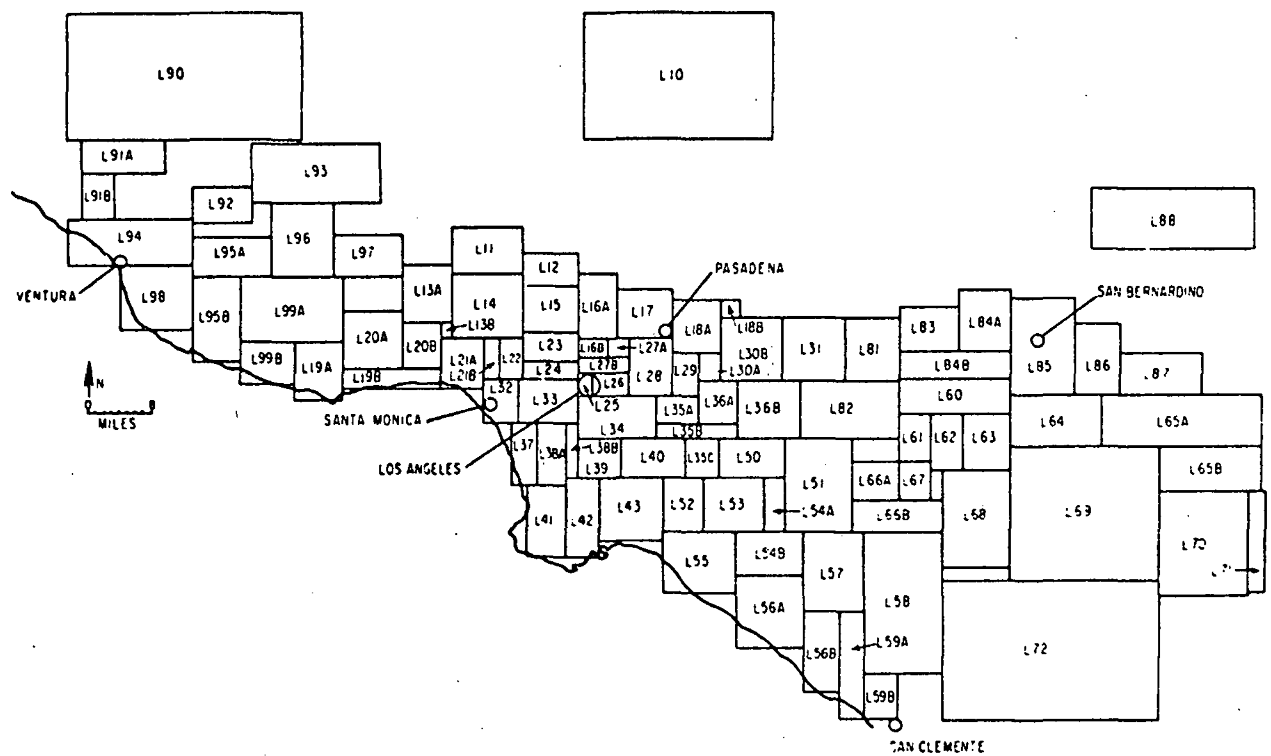


Figure B-5. Los Angeles Stylized Zones

Changes in per-capita income from National Planning Association (NPA, Ref. 40) regional projections were used to adjust the survey data to the calibration year (1967 or 1968). Where available, regional planning organization projections were used directly for 1980. When these were not available, NPA projections were used.

(3) Workforce Size and Income at the Workplace

Special data processing was developed to produce zonal income at the workplace, since these were ordinarily not available from the home survey. Magnetic tape summaries of intracity travel were obtained from each area, and computer programs were developed to extract home-to-work trips by traffic zone and to aggregate these to the study-zone level. For each trip, family income at the zone of origin was then assigned to the corresponding work zone to develop a work-zone income distribution. The results were tabulated to yield the median income and the percent of the regional work force employed within each zone. For NEC regions, the work-trip tapes were also analyzed to yield car availability percentages for each zone.

(4) Hotel/Motel Space

Relative distribution of commercial lodging units by zone was created from lists of major hotels and motels, giving their capacities (obtained from city convention bureaus and hotel owner organizations) and locating each of the hotels on a map of the region. When data were available, planned new hotels were also included in the totals. Total units were then summed for each zone and divided by the regional total to yield a percent hotel/motel distribution in each zone. Since the objective was to develop relative rather than absolute unit densities, motels having less than 50 units were generally omitted in the data tabulation.

A set of zonal characteristics for three zones in the Los Angeles region is presented in Table B-6. Similar data were produced for all zones in all of the regions in the study using the techniques described above. Note that for 1980, there is no prediction of median income at the workplace. This

Table B-6. Sample Zonal Characteristics, Los Angeles

1. Zone Definition						
LARTS Statistical Area	L 37[a]		L 25[a]		L14[a]	
County Statistical Area	31		9		14	
Regional Name	South Bay		Central		Encino	
Stylized Area (Sq. Mi.)	28.0		6.0		76.5	
2. Year	1967	1980	1967	1980	1967	1980
3. Residential Population						
Absolute	174,509	181,612	75,460	78,514	344,422	390,600
% of Total	1.90	1.63	0.82	0.70	3.75	3.49
4. Median Income (dollars)						
Residential	8,329	7,618	3,000	4,027	8,803	9,730
Place of Work	10,042	—	6,426	—	9,754	—
5. Hotel/Motel Availability						
Units	2,867	2,867	4,808	4,808	<100	<100
% of Total	6.83	6.63	14.81	14.81	—	—
6. Travel Demand Distribution						
A. Long Trips						
Percent of:						
• Resident Business Travelers	.44	.21	.03	.03	.61	.62
• Resident Nonbusiness Travelers	.69	.56	.15	.16	1.40	1.36
• Nonresident Business Travelers	.56	.58	.83	.66	.51	.53
• Nonresident Nonbusiness Travelers	1.10	.96	.61	.68	1.09	1.15
B. Short Trips	Similar set for short trips					

[a] See Figure B-5

is because no data were available on projected home-to-work trips, and it was therefore assumed that nonresident business demand would have the same relative zonal distribution in 1980 as it had in 1967. Note also that the hotel/motel units are the same for both the calibration and the forecast year. The actual numbers used reflect the sum of the 1970 existing hotel/motel units available, plus a near-term forecast of additional units already in the planning or construction stage. Because the numbers change slowly, unless dramatic and currently unanticipated changes in land use occur, a single composite figure is reasonable over the time span of interest.

The travel demands shown in Table B-6 reflect those attributable to long intercity distances. For use with shorter-distance trips (i.e., Los Angeles to San Diego), another set of similar demands was generated. Counting all of the zones, regions, distances, and years (calibration and forecast) considered, a total of 13,680 zonal demand values was generated and used in the computations for the three arenas.

Some observations on the relative demands for the three zones highlighted in Table B-6 might be made at this point. Encino is characteristic of a high-income, densely populated residential area; Central is a low-income, business-oriented area, and South Bay is a mixture of residential and business areas. Note that for Encino, the highest travel demand percentage is for residential nonbusiness trips, while for the CBD* there is a predominance of visitor business trips. South Bay contains a variety of traveler types and trip purposes. Note further that in the CBD the worker income is considerably higher than the resident income. Had the latter alone been used to develop trip demand (as is the case in some trip-generation models), a very small number of trips would have been forecast for this area, violating known data to the contrary.

A summary of arena and regional demographic and socioeconomic characteristics is presented in Table B-1. The table presents a number of

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*Central Business District

interesting similarities among the regions as well as some interesting contrasts. In area, the California Corridor is seen to be the largest of the arenas, with the Los Angeles and San Francisco regions each being almost twice the size of any of the other regions. In population, however, the Northeast Corridor is the largest, with the California Corridor second, and the Midwest Triangle third. By far, the New York region has the largest population, being almost double that of Los Angeles and more than three times that of the others. Population growth between 1967 and 1980 appears quite variable, with the California Corridor and Midwest Triangle showing a compound annual growth rate of 1.7 percent and the Northeast Corridor a growth rate of 1.4 percent. On a regional basis, the Washington, D.C. region has the largest growth rate (3.4 percent), while San Diego ranks second with a 3 percent figure. The region with the lowest growth rate is Philadelphia, with an annual increase of only 0.7 percent.

The 1980 population and area figures shown were combined to compute the projected 1980 population density on a person-per-square-mile basis, shown in column six of Table B-1, since it is this factor that is perhaps more significant in transportation analyses. It is seen that the Northeast Corridor ranks highest in population density, with the Midwest Triangle second, and the California Corridor third. With the exception of Los Angeles, all of the California regions studied are less than 1,000 persons per square mile, while most of the Midwest and Northeast cities are above 1500 persons per square mile. The New York region ranks highest with a density of over 6,000 persons per square mile.

A review of income characteristics for the various arenas indicates that the Midwest Triangle has the highest median income, with the Northeast Corridor second, and the California Corridor third. This order will still be valid in the 1980 time period. The Chicago and Washington, D.C. regions have the highest incomes and Los Angeles the lowest. A calculation of compound annual growth rates would indicate that San Diego has the highest expected income growth rate (6 percent) with Sacramento second at 4.4 percent, Chicago third at 4.3 percent, and Washington D.C. fourth at 4.2 percent.

The final factor shown in Table B-1 is the number of hotel/motel units in each region. The Midwest Triangle has the largest number, with the Northeast Corridor second, and the California Corridor third. The Chicago region ranks first, having almost twice as many hotel/motel units as the New York region. Some insight into the relative significance of these figures can be obtained by estimating hotel/motel units on a per-capita basis. Dividing by the 1980 populations, it can be calculated that the San Diego region has the greatest per capita spaces with 13.9 units per thousand population. The Chicago region ranks second with 12.8 per thousand, and Washington, D.C. ranks third with 8.5. This is certainly expected, since San Diego is largely a vacation and resort city, Chicago is the major trade center in the Midwest, and Washington is the center of government services. The remaining regions generally have hotel/motel unit densities in the range of 2.7 through 3.9 with the exception of San Francisco, which has 5.0 per thousand.

b. Intercity Transportation Port Characteristics

All current CTOL airports that support service between a given city pair were modeled explicitly. For the bus mode, only the downtown ports were used for the long-distance city pairs, since most of the long-haul bus trips made few or no stops at other ports within the city. For shorter distances these extra stops were common, so in these cases additional bus stops were modeled. For those city pairs having rail services, only the downtown port was used in the California and Midwest arenas, but multiple ports were specified in the Northeast arena. Selection and siting of STOLports is discussed in Appendix D.1.

Car "ports" were located on major highways at the periphery of the regions. These represent the points of departure for intercity travel. Access time and costs from the traveler's exact point of origin or destination to these ports were obtained from the local car-travel functions. Therefore, the effects of peak-period intracity traffic were modeled for local access to the carports as well as to those of other modes of transportation.

Odd-numbered figures in Appendix D and Figures 11 through 21 in Volume I (Ref. 39) show these port locations. Tables B-7 through B-9 describe the port processing time, parking time, and parking cost characteristics of each port simulated in this study. The following paragraphs describe how these characteristics were developed.

(1) Port Processing Time

The port processing times reflect estimated durations of time that a typical passenger will spend within the identified terminals of the specified mode of transportation. These figures represent average passenger times associated with entry or exit from the terminal curb through the boarding or unloading gates of the mode of transportation including walking, reservations, schedule lead time, ticketing, and (in some cases) baggage-handling processes. In many cases, the times were obtained by physical demonstration of a typical commuter passenger in selected terminals. Data on port processing times for all major CTOL, rail, and bus ports were developed for DOT's NECTP study (Ref. 38) and were used in estimating the off-peak processing times shown in the port characteristics tables. The peak processing times were developed by adding zero, 3 minutes, or 6 minutes to the off-peak times, depending upon the total volume of traffic at the CTOLports. STOLport processing times were assumed to be 14.5 minutes, and no distinction was made between the peak and off-peak processing times since it was assumed that the STOLport design could accommodate peak traffic in the times shown.

The CTOLport processing times were found to vary largely as a function of airport congestion and walking distance between the terminal entrance and the arrival or departure gate. Thus, at the larger airports served by CTOL the processing times are generally longer than at the medium and smaller airports. Car processing times were zero, since it was assumed that the traveler had immediate access to this mode.

(2) Port Parking Time and Cost

Port parking time was defined as the time necessary to enter the parking lot, occupy a parking stall, and walk to the transportation mode

Table B-7. California Corridor Port Characteristics

City	Mode	Port Abbre-viation	Port Description	Processing Time Off-Peak (Hrs)	Processing Time Peak (Hrs)	Parking Time (Hrs)	Parking Cost ($/Day)
Los Angeles	CAR	LGOR	Gorman	0.0	0.0	0.0	0.0
		LSFV	San Fernando	0.0	0.0	0.0	0.0
		LOXN	Oxnard	0.0	0.0	0.0	0.0
		LSNA	Santa Ana	0.0	0.0	0.0	0.0
		LRIV	Riverside	0.0	0.0	0.0	0.0
		LCAP	Capistrano	0.0	0.0	0.0	0.0
	CTOL	LLAX	L.A. Int'l	0.31	0.41	0.12	3.00
		LBUR	Burbank	0.29	0.34	0.12	3.00
		LONT	Ontario	0.29	0.29	0.08	1.50
		LLGB	Long Beach	0.29	0.29	0.06	1.00
		LSNA	Santa Ana	0.28	0.28	0.06	2.00
	BUS	LCBD	CBD	0.16	0.20	0.10	2.40
		LLGB	Long Beach	0.16	0.16	0.05	0.50
		LSNA	Santa Ana	0.16	0.16	0.05	0.50
		LSB	San Bernardino	0.16	0.16	0.05	0.50
	RAIL	LCBD	CBD	0.21	0.21	0.10	1.75
	STOL	LCBD	CBD (Patton)	0.24	0.28	0.07	3.00
		LFULL	Fullerton	0.24	0.24	0.05	1.50
		LTRI	Tri-City	0.24	0.24	0.05	1.00
		LVAN	Van Nuys	0.24	0.24	0.05	3.00
		LMON	El Monte	0.24	0.24	0.05	2.00
San Francisco	CAR	FSJ	San Jose	0.0	0.0	0.0	0.0
		FVAL	Vallejo	0.0	0.0	0.0	0.0
		FDAV	Davis	0.0	0.0	0.0	0.0
	CTOL	FSFO	S. F. Int'l	0.30	0.40	0.13	2.75*
		FSJC	San Jose	0.29	0.29	0.09	2.50*
		FOAK	Oakland	0.31	0.31	0.09	2.00
	BUS	FCBD	CBD	0.16	0.20	0.10	3.50
		FOAK	Oakland	0.16	0.16	0.05	1.00
		FSJ	San Jose	0.16	0.16	0.05	0.50
		FWOD	Woodland	0.16	0.16	0.05	0.50
	RAIL	FCBD	CBD	0.21	0.21	0.05	2.00
	STOL	FCBD	CBD (India Basin)	0.24	0.28	0.07	2.50
		FPALO	Palo Alto	0.24	0.24	0.05	2.00
		FCONC	Concord	0.24	0.24	0.05	1.50
Sacramento	CAR	SCBD	Downtown	0.0	0.0	0.0	0.0
		SDAV	Davis	0.0	0.0	0.0	0.0
		SGALT	Galt	0.0	0.0	0.0	0.0
	CTOL	SSMF	Metropolitan	0.29	0.29	0.07	1.50*
	BUS	SCBD	CBD	1.16	0.20	0.10	2.20
	STOL	SMUN	Sac. Executive	0.24	0.24	0.05	1.50

* First day rate. Additional days at a different rate.

Table B-7. California Corridor Port Characteristics (continued)

City	Mode	Port Abbreviation	Port Description	Processing Time Off-Peak (Hrs)	Processing Time Peak (Hrs)	Parking Time (Hrs)	Parking Cost ($/Day)
San Diego	CAR	DCBD	Downtown	0.0	0.0	0.0	0.0
		DOCN	Oceanside	0.0	0.0	0.0	0.0
		DRIV	North Central	0.0	0.0	0.0	0.0
	CTOL	DSAN	Lindbergh	0.31	0.31	0.10	2.00
	BUS	DCBD	CBD	0.16	0.20	0.10	1.50
		DOCN	Oceanside	0.16	0.16	0.05	1.00
	RAIL	DCBD	CBD	0.21	0.21	0.10	1.00
	STOL	DMON	Montgomery	0.24	0.24	0.05	1.00

Table B-8. Midwest Triangle Port Characteristics

City	Mode	Port Abbreviation	Port Description	Processing Time Off-Peak (Hrs)	Processing Time Peak (Hrs)	Parking Time (Hrs)	Parking Cost ($/Day)
Chicago	CAR	CCHI	East State Line	0.0	0.0	0.0	0.0
	CTOL	COHARE	O'Hare	0.32	0.42	0.15	2.25
		CMDWAY	Midway	0.31	0.36	0.09	2.25
		CMIEGS	Meigs	0.29	0.29	0.06	2.25
	BUS	CCBD	CBD	0.16	0.20	0.10	3.50
	RAIL	CCBD	CBD	0.21	0.26	0.10	2.50
	STOL	CMIEGS	Meigs	0.24	0.28	0.07	2.25
		CMIT	Mitchel	0.24	0.24	0.05	1.50
Detroit	CAR	DCHL	Chelsea	0.0	0.0	0.0	0.0
		DROC	Rockwood	0.0	0.0	0.0	0.0
		DTOL	Toledo	0.0	0.0	0.0	0.0
	CTOL	DMETRO	Metropolitan	0.29	0.37	0.10	3.00
		DCITY	Detroit City	0.29	0.29	0.05	1.50
	BUS	DCBD	CBD	0.16	0.20	0.10	3.00
	RAIL	DCBD	CBD	0.21	0.21	0.10	1.00
	STOL	DCITY	Detroit City	0.24	0.24	0.05	1.50
		DBERZ	Berz	0.24	0.24	0.05	1.00
		DMETT	Mettetal	0.24	0.24	0.05	1.00
Cleveland	CAR	VAMH	Amherst	0.0	0.0	0.0	0.0
		VLOR	Lorraine	0.0	0.0	0.0	0.0
	CTOL	VHOPKN	Hopkins	0.32	0.37	0.05	2.25
		VBURKE	Burke Lakefront	0.30	0.30	0.07	1.50
	BUS	VCBD	CBD	0.16	0.20	0.10	1.25
	RAIL	VCBD	CBD	0.21	0.21	0.10	2.00
	STOL	VBURKE	Burke Lakefront	0.24	0.24	0.07	1.50
		VBOS	Bosworth	0.24	0.24	0.05	1.00

Table B-9. Northeast Corridor Port Characteristics

City	Mode	Port Description	Code	Processing Time Off-Peak (Hrs)	Processing Time Peak (Hrs)	Parking Time (Hrs)	Parking Cost ($/Day)
Boston	CAR	Rt. 122 & Mass.TPK	BOS1	0.0	0.0	0.0	0.0
		I-95 & I-495	BOS2	0.0	0.0	0.0	0.0
		Rt. 128 & Mass. TPK	BOS3	0.0	0.0	0.0	0.0
	STOL	Logan Int'l	BLOGS	.24	.24	.07	2.50
		Bedford	BBED	.24	.24	.05	1.00
	CTOL	Logan Int'l	BOS	.27	.32	.10	2.50
	BUS	CBD	BOSB	.16	.20	.10	3.00
		Newton	NEWT	.16	.16	.10	1.00
	RAIL	South Station	BOSR	.21	.31	.05	2.00
		Route 128R	128R	.21	.21	.05	0.50
New York City	CAR	Jamesburg N.J.	NYC1	0.0	0.0	0.0	0.0
		Mt. Kisco-Saw Mill R. Pky.	NYC2	0.0	0.0	0.0	0.0
		Port Chester	NYC3	0.0	0.0	0.0	0.0
		Stratford Conn.	NYC4	0.0	0.0	0.0	0.0
	STOL	Secaucus	NSEC	.24	.28	.05	2.50
		Mitchell Field	NMITCH	.24	.24	.05	2.00
		Westchester County	NWES	.24	.24	.05	N.C.
	CTOL	J.F.K.	JFK	.30	.40	.10	6.00
		LaGuardia	LGA	.25	.35	.10	3.00
		Newark	EWR	.26	.31	.10	2.00*
		Westchester County	HPN	.30	.30	.05	N.C.
		Islip	ISP	.25	.25	.05	N.C.
		Bridgeport	BDR	.25	.25	.05	N.C.
	BUS	N.Y. Port Authority	PABT	.20	.30	.05	4.75
		Geo. Wash. Bridge	GWBT	.16	.20	.10	3.00
		Bridgeport	BRIB	.16	.20	.05	1.50
		White Plains	WPB	.16	.20	.10	1.50
		E. Brunswich	BRUN	.16	.16	.10	1.00
		Newark	EWRB	.16	.20	.10	2.50
	RAIL	N.Y. Penn. Sta.	PENN	.22	.32	.15	4.75
		Stanford	STAM	.21	.26	.05	1.75
		Newark	EWRR	.21	.31	.05	0.80
		(Metroport N.J.)	METR	.20	.20	.10	1.50
Philadelphia	CAR	Chester Pa.	PHL1	0.0	0.0	0.0	0.0
		NJ TPK & Trenton	PHL2	0.0	0.0	0.0	0.0
		Moorestown N.J.	PHL3	0.0	0.0	0.0	0.0
	STOL	No. Philadelphia	PNPHLS	.24	.24	.05	1.00
	CTOL	Philadelphia Int'l	PHL	.32	.42	.10	2.00
	BUS	Philadelphia	PHLB	.17	.22	.10	2.50
		Moorestown	MORB	.16	.16	.10	1.00
		Chester	CHSB	.16	.16	.10	1.00
	RAIL	Philadelphia	PHLR	.20	.30	.10	2.10
		Trenton	TTNR	.20	.25	.10	2.10

Table B-9. Northeast Corridor Fort Characteristics (continued)

City	Mode	Port Description	Code	Processing Time Off-Peak (Hrs)	Processing Time Peak (Hrs)	Parking Time (Hrs)	Parking Cost ($/Day)
Wash. D.C.	CAR	Meade Md.	WAS1	0.0	0.0	0.0	0.0
		Beltway	WAS2	0.0	0.0	0.0	0.0
	STOL	College Park	WCOLL	.24	.28	.05	1.00
		Prince Georges	WPG	.24	.24	.05	N.C.
	CTOL	Dulles	IAD	.24	.29	.10	1.50
		Wash. National	DCA	.25	.35	.08	3.20
	BUS	Wash. D.C. - CBD	WASB	.16	.20	.10	3.00
		Laurel	LAUB	.16	.16	.10	1.00
	RAIL	Wash. D.C. -CBD	WASR	.21	.31	.07	3.75
		Beltway	BELT	.21	.21	.05	1.00

* First day rate. Additional days at a different rate.

terminal entrance. The time was considered to be an average for both port-arriving and port-departing travelers and was obtained by both physical survey and telephone conversations with port authorities. These times were found to vary as a function of the size of the parking facility provided, the level of passenger/visitor parking demand at the port, and the distance of the parking facility from the terminal. For the CTOLports, parking times were computed by assuming 2 minutes required for parking and unloading baggage plus the walk time from the parking lot to the terminal based on measured distances and a walk speed of 3 ft/sec. The actual walk time used represented a distance greater than the average distance to the terminal but less than the maximum. An additional time of 3 minutes was added to the large CTOLports to account for effects of ramps and stairs at parking structures, pedestrian traffic lights in the terminal area, etc.

For STOLports, it was assumed that the overall design would accommodate a parking time of 3 minutes. An additional minute was added to STOLports in central business district (CBD) locations to account for congestion effects. The automobile mode of intercity transportation assumed zero port-parking time.

The parking costs were determined from physical surveys as well as telephone conversations with parking lot concessionaires at the actual port. In those cases (bus and some rail ports) where 24-hour auto parking was not provided or was discouraged, the costs represented those charged by parking lots located in the immediate vicinity of the terminal. In all cases the cost presented in the tables of port characteristics reflects the first 24-hour rate. Variation of rates associated with second-day parking (e.g., LAX is $4.00) are not shown but were used in the calculations. For STOLports the parking costs were determined by classifying each STOLport location in terms of CBD, suburban, and rural, and then assigning parking costs consistent with existing CTOL, bus, or rail terminals in comparable locations.

c. Local Transportation Characteristics

The cost and time to get from a travelers origin to a port, or from the destination port to the final destination, is made up of two elements. The first element is a cost and time based strictly on the rectangular distance traveled. This local travel function may differ from superzone to superzone in each city and is generally different within a superzone for peak and off-peak periods. The second element is an additional time and cost penalty incurred whenever local travel crosses superzone boundaries, and it is used to reflect tolls and delays at bridges and tunnels or the penalty associated with having to go around local travel barriers.

Subsection (1) discusses the formation of superzone boundaries in the cities modeled and what local modes were represented by the local travel functions in these superzones. Subsection (2) discusses how local travel functions are formed and presents car-speed data for local trips from each of the cities modeled. Subsection (3) addresses the formation of intersuperzone penalties and presents the specific penalties used in this study.

(1) Superzone Formation and Associated Local Travel Modes

Superzone modeling is a recent addition to the modal-split simulation. It was introduced to better model cities, such as New York, which contain many restrictions to local travel within its borders. Thus, all of the NEC

cities were superzoned as part of their initial modeling. Cities in the Midwest and California had already been modeled as part of earlier studies and, with the single exception of San Francisco, were not superzoned. San Francisco was superzoned because of the significant restrictions to local travel caused by water barriers.

In the California Corridor, each of the larger cities (Los Angeles and San Francisco) had four local travel functions: drive and park for peak and off-peak, and a composite local mode for peak and off-peak. The composite-mode structure is based on a general "kiss-and-ride" mode, but reflects the weighted combination of public modes usually available for port access (taxi, airport bus, local bus) in cities without an extensive rapid transit network. The smaller cities (San Diego and Sacramento) had two local travel functions -- drive and park, and composite -- with no differentiation between peak and off-peak.

Although San Francisco did not have separate local travel functions assigned on a superzone basis, it nevertheless had a large number of superzones (see Figure B-6) to properly reflect the various bridge crossings of San Francisco and San Pablo Bay. For example, SNMAT had to be separate from FRSCO and HYWRD separate from OKLND in order to reflect the use of the San Francisco - Oakland Bay Bridge between downtown San Francisco and Oakland and the San Mateo or Dumbarton Bridge between areas located on opposite sides of lower San Francisco Bay. Similarly, the various uses of the Golden Gate, Richmond - San Rafael, and Carquinez Bridges led to the formation of superzones MARIN, SLANO, and CCSTA.

In the Midwest Triangle all three cities had four local travel functions: drive and park for both peak and off-peak, and the composite mode for both peak and off-peak.

In the Northeast Corridor all of the cities were superzoned and specific local travel functions assigned on this basis. Cities in this corridor will be discussed individually.

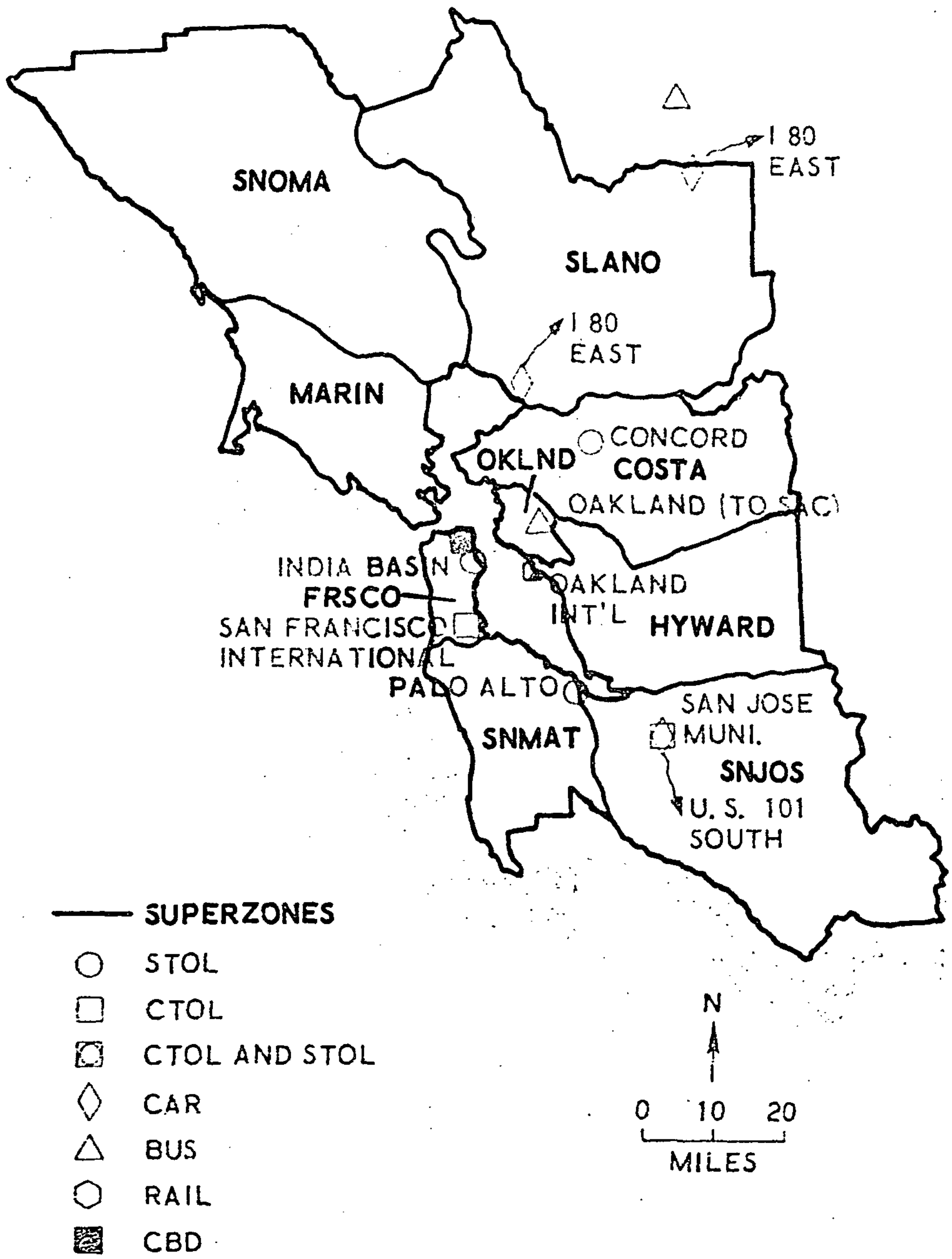

Figure B-6. San Francisco Superzones

The New York superzones are shown in Figure B-7. Based on general speed of local travel, the New York area was broken up into three sets of superzones:

- The CBD (MAN-Manhattan)
- The moderate-density urban areas (QNBK - Queens Brooklyn, BRX-Bronx, JN-New Jersey North, and JS-New Jersey South)
- The lower-density areas (STN-Staten Island, LI-Long Island, JRN-New Jersey Rural North, JRS-New Jersey Rural South, and BASE-Westchester County and Southern Connecticut).

The breakdown within superzone sets is required to reflect the choice of bridges and tunnels in and about Manhattan. For example, dividing New Jersey into northern and southern sections reflects the choice of crossing the Hudson via Staten Island or via Manhattan.

MAN has six unique local travel functions which are not used for any other superzones: drive and park, taxi, and subway/bus for both peak and off-peak periods. QNBK and BRX have a different set of six functions for these same local modes. JN and JS uses the same taxi and drive and park functions as QNBK and BRX, but use a pair of kiss-and-ride functions rather than subway/bus. The five remaining superzones had a common set of four local travel functions: drive and park and composite for both peak and off-peak periods.

Philadelphia has four superzones as shown in Figure B-8. Philadelphia CBD (PCBD) has six local travel functions: drive and park, composite, and subway/bus for peak and off-peak periods. Camden CBD (CCBD) uses the same functions as PCBD except it does not have the pair of subway/bus modes. Rural New Jersey (RNJ) and Rural Philadelphia (BASE) share a different set of four functions: drive and park, and composite local modes for both peak and off-peak periods.

The Boston superzones are shown in Figure B-9. Boston is broken into three sets of superzones based on local travel speeds:

- The CBD (TOWN)
- The rest of the area generally inside the Route 128 loop (BEACH, NRING - North Ring, and SRING - South Ring)

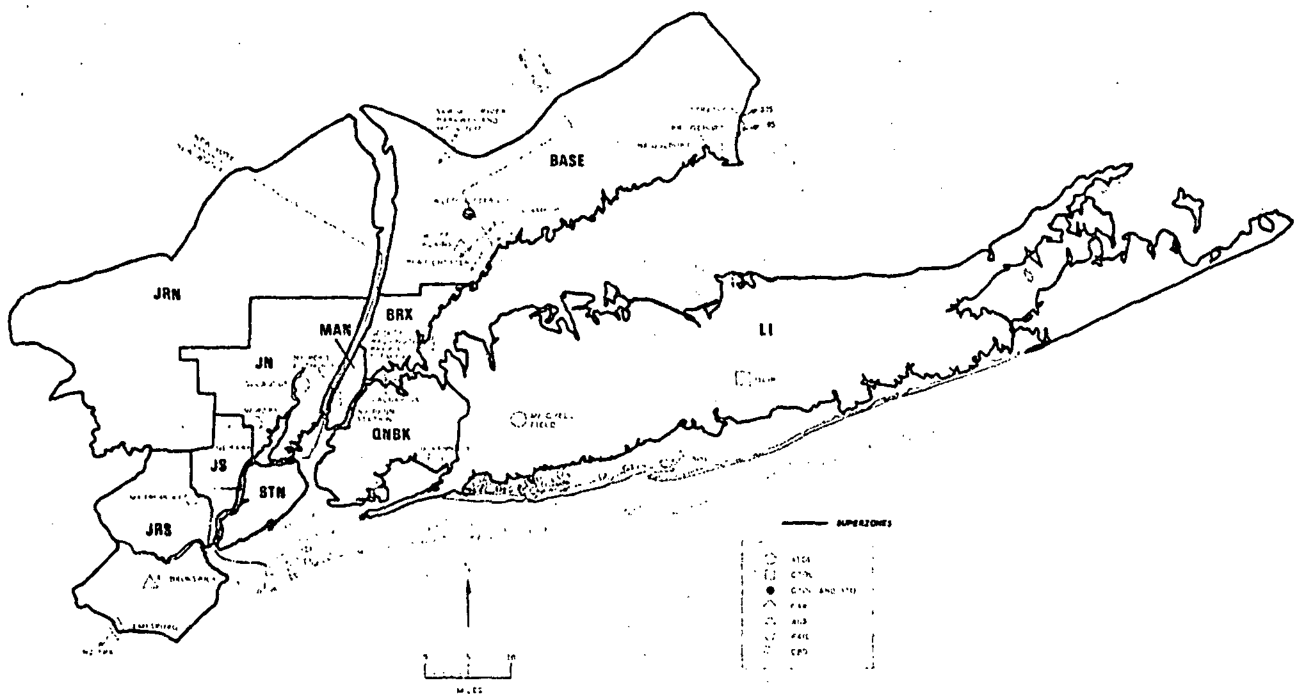

Figure B-7. New York Superzones

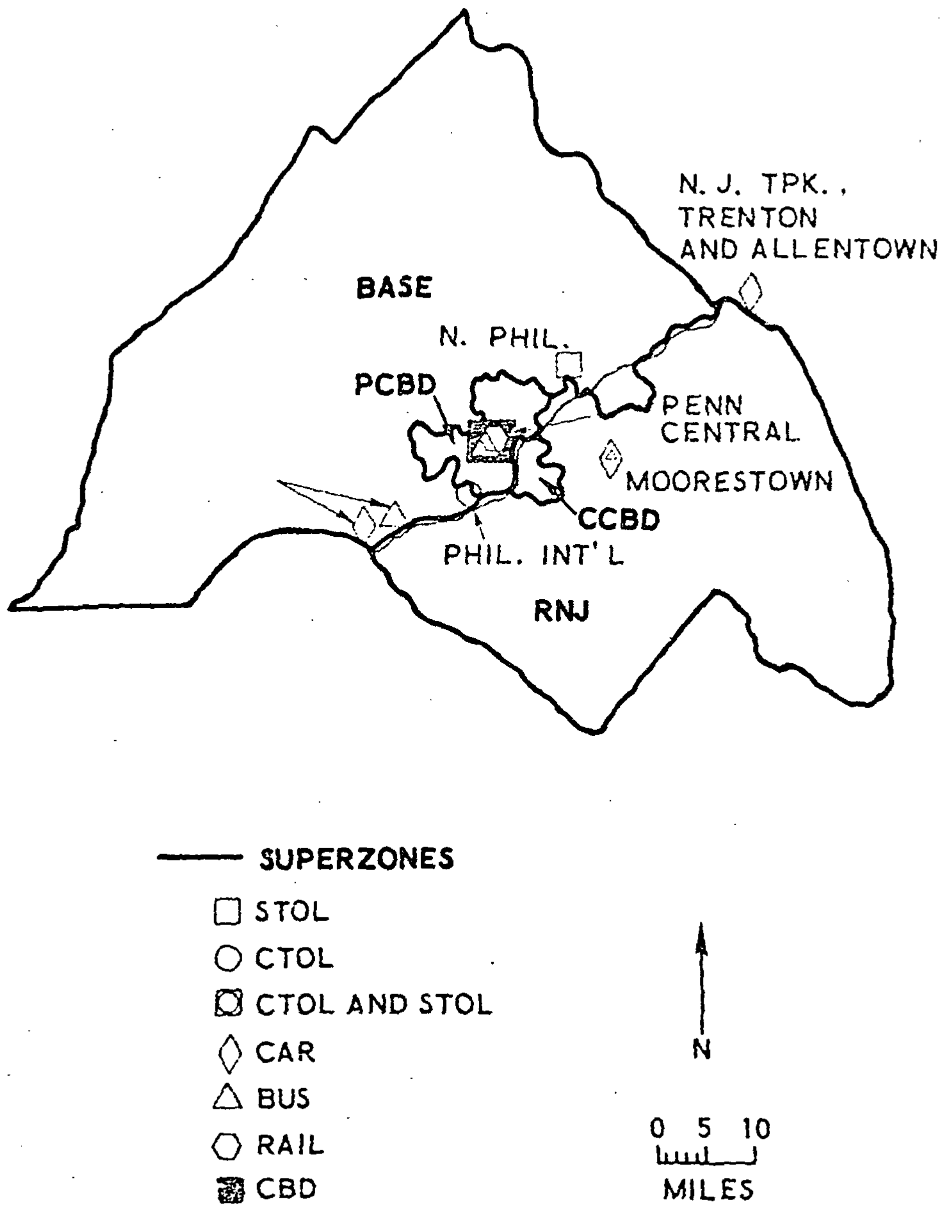

Figure B-8. Philadelphia Superzones

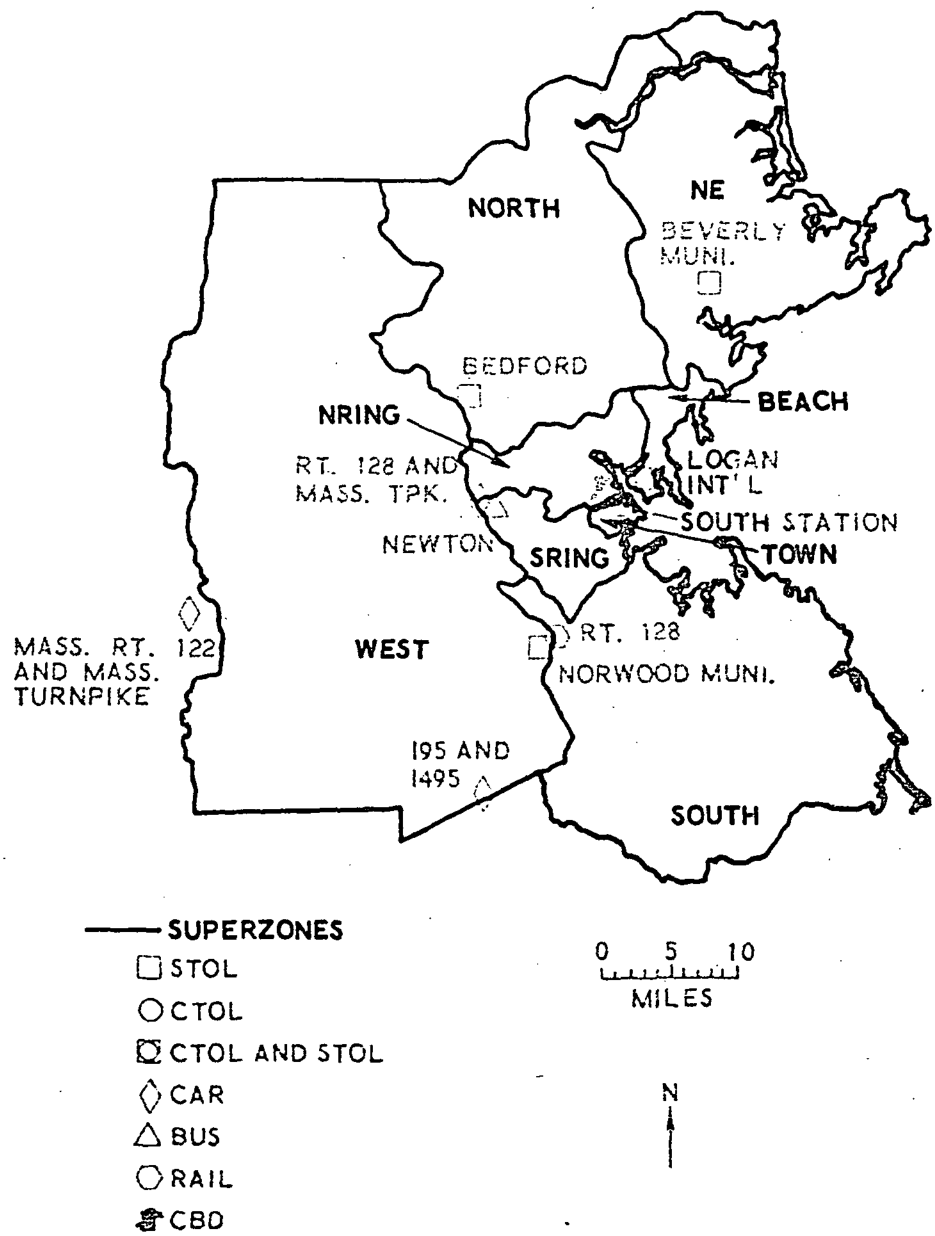

Figure B-9. Boston Superzones

- The area outside of Route 128 (NE-Northeast, NORTH, WEST, and SOUTH).

TOWN has a separate set of six local travel functions: drive and park, taxi, and subway/bus for peak and off-peak periods. BEACH, NRING, and SRING use a different set of 4 functions for drive and park and subway/bus, and then have a pair of kiss-and-ride functions rather than taxi. Finally, the remaining superzones have two local travel functions: drive and park and composite, which are used for both peak and off-peak periods.

Washington was divided into three sets of superzones based on local travel speeds, and is further divided within these sets due to the bridges spanning the Potomac River (see Figure B-10).

- The innermost pair of superzones (DC and ARL - Arlington) have four local travel functions: drive and park, and composite for both peak and off-peak periods.
- The middle set of superzones (MN-Maryland North, MS-Maryland South, and VIR-Virginia) generally covers the remaining area inside the Route 495 loop. These superzones share four drive and park and composite local travel functions having intermediate speed profiles.
- The remaining three superzones (MNR-Maryland North Rural, MSR-Maryland South Rural, and VIRR-Virginia Rural) have yet another set of four local travel functions for drive and park, and composite for both peak and off-peak periods.

(2) Local Travel Functions

This subsection discusses how the local travel modes introduced in the previous subsection are represented by local travel functions in the modal split simulation model.

Car mode (drive and park) was an option in superzones of all cities. Car cost was based on a perceived direct-operating cost of 4 cents per mile (excluding such fixed costs as depreciation and insurance), since various studies indicated that this was the perceived cost used by the public in making mode-choice decisions. It should be noted that recent gasoline shortages and price increases tend to make this figure optimistic, and thus the forecast for the 1980 air modal split developed herein is probably lower than what may actually be achieved.

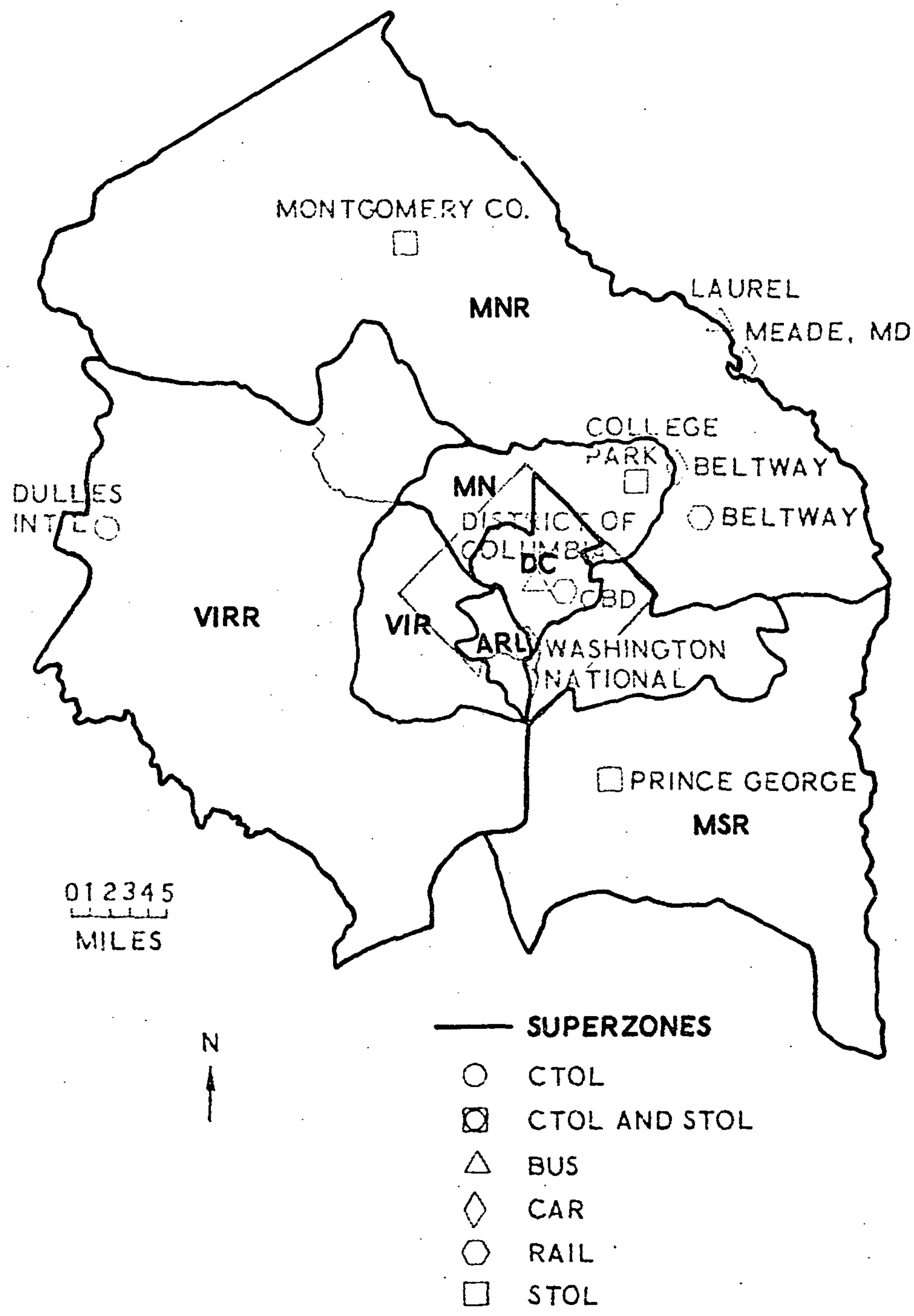

Figure B-10. Washington, D. C. Superzones

Travel times associated with local car usage are based on data supplied by the cities themselves (see Section B-5). To give a feeling for the local car-speed variance from city to city, Table B-10 presents the average speed achieved by auto over a 5-mile intrasuperzone trip for both peak and off-peak periods. San Diego and Sacramento use the same values for these two periods since there is not a significant data base indicating different values for these periods. Cities in the NEC show a range of values for each period, indicating the variance from superzone to superzone.

Composite local travel, taxi, and bus timelines are based primarily on these same auto timelines. Costs are unique to each mode. For example, taxi cost is modeled as an initial charge (i.e., a cost associated with zero miles) plus a per-mile charge, then an additional charge for time

Table B-10. Average Auto Speeds for a 5-Mile Local Trip

	Peak Period (mph)	Off-peak Period (mph)
Los Angeles	18.8	25.0
San Francisco	18.8	25.0
San Diego	30.0	30.0
Sacramento	30.0	30.0
Chicago	18.8	24.0
Detroit	15.0	19.1
Cleveland	16.2	22.0
New York	12.5 to 25.0	17.6 to 34.1
Philadelphia	15 to 20	25 to 30
Boston	17.4 to 34.1	24.6 to 34.1
Washington	15 to 25	25 to 35

which is converted using speed to another per-mile charge. Subway is modeled as a constant charge independent of distance, but it has an initial time penalty (for zero distance) representing the requirement for walking to the station and waiting for the next vehicle. The data for forming the rest of the subway timeline were obtained from local agencies.

(3) Intersuperzone Cost and Time Penalties

When local travel crosses superzone boundaries, additional cost and time penalties may be added. The time penalty may be different for peak and off-peak periods to reflect the added congestion at tunnels and bridges or the extra delay in passing through the CBD.

Tables B-11 through B-15 present printouts of 1980 penalties assigned between superzones in San Francisco, New York, Philadelphia, Boston, and Washington, the cities which were superzoned.

In the case of San Francisco and New York, some negative numbers appear for both cost and time. This is due to the fact that in certain superzones of these cities the principal highways do not run north-south and east-west. In particular, Long Island (LI) in New York and SNJOS, SNMAT, and HYWRD in the San Francisco Bay area have this characteristic. In certain superzone combinations involving these superzones, it is typical for the traveler to move diagonally rather than rectangularly relative to the principal local travel axes set up for those cities. Hence, he really has to travel fewer miles than indicated by differencing his local origin and destination coordi nates. Negative cost and time penalites were used to correct for this phenomenon. Likewise, in certain cases, the typical local travel path may be longer than the rectangular measure. In these cases an additional penalty is added.

If a superzone pair does not appear in the table, it does not have a cost or time penalty.

B.4 INTERCITY TRAVEL CHARACTERISTICS

A key element, critical to the question of whether a new mode of commercial transportation can be successfully introduced into any given

Table B-11. San Francisco Intersuperzone Penalties

Superzone Pair		Cost Penalty (dollars)	Off-Peak Time Penalty (hours)	Peak Time Penalty (hours)
MARIN	SNOMA	0.	0.	0.
MARIN	SLANO	.20	.1	.1
MARIN	CCSTA	.50	0.	0.
MARIN	OKLND	.50	.1	.7
MARIN	HYWRD	.50	.1	.7
MARIN	SNJOS	-.15	-.1	.25
MARIN	SNMAT	.05	0.	.35
MARIN	FRSCO	.25	.05	.35
SNOMA	SLANO	0.	0.	0.
SNOMA	CCSTA	.375	.1	.1
SNOMA	OKLND	.275	.05	.05
SNOMA	HYWRD	.175	0.	0.
SNOMA	SNJOS	-.15	-.1	.25
SNOMA	SNMAT	.05	0.	.35
SNOMA	FRSCO	.25	.05	.35
SLANO	CCSTA	.175	0.	0.
SLANO	OKLND	.175	0.	0.
SLANO	HYWRD	.175	0.	0.
SLANO	SNJOS	.175	0.	0.
SLANO	SNMAT	.625	.1	.1
SLANO	FRSCO	.425	.05	.35
CCSTA	OKLND	0.	0.	0.
CCSTA	HYWRD	-.20	-.1	-.1
CCSTA	SNJOS	-.40	-.2	-.2
CCSTA	SNMAT	.55	.1	.1
CCSTA	FRSCO	.25	.05	.35
OKLND	HYWRD	-.10	-.05	-.05
OKLND	SNJOS	-.30	-.15	-.15
OKLND	SNMAT	.55	.1	.1
OKLND	FRSCO	.25	.05	.35
HYWRD	SNJOS	-.20	-.1	-.1
HYWRD	SNMAT	.30	-.05	-.05
HYWRD	FRSCO	.30	.05	.225
SNJOS	SNMAT	-.20	-.1	-.1
SNJOS	FRSCO	-.40	-.15	-.1
SNMAT	FRSCO	-.20	-.05	0.

Table B-12. New York Intersuperzone Penalties

Superzone Pair		Cost Penalty (dollars)	Off-Peak Time Penalty (hours)	Peak Time Penalty (hours
MAN	QNBK	0.27	0.06	0.15
MAN	LI	0.25	0.04	0.12
MAN	BRX		0.02	0.06
MAN	BASE	0.25		0.03
MAN	STN	0.91	0.12	0.34
MAN	JN	0.54	0.08	0.23
MAN	JS	1.41	0.12	0.33
MAN	JRN	0.54	0.07	0.20
MAN	JRS	1.41	0.12	0.33
QNBK	LI	-0.16	-0.09	-0.13
QNBK	BRX	0.25		0.07
QNBK	BASE	0.50		0.07
QNBK	STN	0.50		0.05
QNBK	JN	0.81	0.14	0.38
QNBK	JS	1.0		0.05
QNBK	JRN	0.79	0.05	0.18
QNBK	JRS	1.0		0.05
LI	BRX	0.53	0.16	0.30
LI	BASE	2.06	0.65	0.77
LI	STN	0.30	-0.11	-0.11
LI	JN	0.75	0.09	0.30
LI	JS	0.90	-0.06	-0.03
LI	JRN	0.75	0.02	0.13
LI	JRS	0.80	-0.11	-0.11
BRX	BASE	0.25		
BRX	STN	1.03	0.04	0.11
BRX	JN	0.54	0.02	0.08
BRX	JS	0.75		0.05
BRX	JRN	0.54	0.02	0.08
BRX	JRS	0.84		0.05
BASE	STN	1.33	0.04	0.06
BASE	JN	0.75		
BASE	JS	1.07		
BASE	JRN	0.73		
BASE	JRS	1.07		
STN	JN	0.5		
STN	JS	0.54	0.03	0.03
STN	JRN	0.71		
STN	JRS	0.5		
JN	JS	0.10		
JN	JRS	0.32		
JS	JRN	0.13		
JS	JRS	0.12		
JRN	JRS	0.36		

Table B-13. Philadelphia Intersuperzone Penalties

Superzone Pair		Cost Penalty (dollars)	Off-Peak Time Penalty (hours)	Peak Time Penalty (hours)
PCBD	CCBD	0.50	0.083	0.15
PCBD	RNJ	0.50	0.083	0.15
CCBD	BASE	0.20	0.05	0.75
RNJ	BASE	0.05	0.05	0.05

Table B-14. Boston Intersuperzone Penalties

Superzone Pair		Cost Penalty (dollars)	Off-Peak Time Penalty (hours)	Peak Time Penalty (hours)
TOWN	BEACH	.20	.017	.05
TOWN	SRING	.20	0.	.033
TOWN	NE	.20	.017	.05
TOWN	WEST	.55	0.	0.
TOWN	SOUTH	0.	0.	.05
BEACH	NRING	0.	.05	.1
BEACH	SRING	.30	.05	.1
BEACH	WEST	.50	.05	.133
BEACH	SOUTH	.2	.05	.133
NRING	SOUTH	0.	.017	.1
SRING	NORTH	0.	0.	.033
NE	SRING	.30	.05	.117
NE	SOUTH	.20	.05	.117
SOUTH	NORTH	0.	.05	.117

Table B-15. Washington, D.C. Intersuperzone Penalties

Superzone Pair		Cost Penalty (dollars)	Off-Peak Time Penalty (hours)	Peak Time Penalty (hours)
DC	ARL			0.083
DC	VIR			0.083
DC	VIRR			0.083
DC	MSR			0.083
DC	MS			0.083
MN	MS			0.083
MN	ARL			0.083
MN	VIR			0.083
MN	VIRR			0.083
MS	ARL	0.20	0.167	0.25
MS	VIR	0.10	0.083	0.167
MS	VIRR			0.083
MNR	ARL			0.083
MNR	VIR			0.083
MNR	VIRR			0.083
MSR	ARL			0.083
MSR	VIR			0.083
MSR	VIRR			0.083

arena, is the definition of the level of total travel demand that must be satisfied and the characteristics of the other modes with which the new one must compete. To define this background environment, travel levels via all modes were obtained for a baseline year. These data were then used in their modal breakdown to calibrate the modal-split computer model (see Appendix C for details) and in aggregate as the basis for forecasting 1980 total travel demand between each city pair. The following sections describe the data collection process, demand forecasting technique and results, and the projection of service for each of these modes as anticipated for 1980.

a. Data Base Development

(1) Auto Demand

Auto-demand data were developed from cordon surveys of each region conducted by each state's Division of Highways. Computer-sorting

program runs selected trips between specific regional pairs from vehicle trips originating within the cordon to all destinations. Truck trips and other commercial trips were then eliminated, as well as through-trips (i.e., those which passed through the cordon area but did not have both regions as an origin or destination). Car-occupancy data were used to convert the vehicle-trip data to total daily one-way/person trips for each city pair.

The year chosen for calibration of the California and Midwest arenas was 1967. The LARTS survey of that year thus provided auto-demand data from Los Angeles to other cities in the California Corridor. For city pairs which did not involve Los Angeles and for all city pairs in the Midwest Corridor, cordon-survey data from previous years were extrapolated to develop 1967 demands. This was done by using the auto person-trip data for the survey year, adding in the available trip data for other modes to get total demand for that year, and using the Aerospace intercity travel-demand model, discussed in the Subsection (2), to project total travel demand in 1967. Available demand data for 1967 for all other modes were then subtracted from the total demand to estimate the 1967 auto demand. Table B-16 contains these data for each city pair within the two arenas in terms of person-trips and as a percentage modal split.

In the NEC, data on the 1968 auto demand (and other modes as well) from DOT's NECTP study (Ref. 38) provided the basis for the data shown in Table B-17.

(2) Air Demand

In the California Corridor, the Public Utilities Commission (PUC) supplied origin/destination data on airline routes of all first, second, and third-level carriers. In the Midwest Triangle, CAB data were used for first and second-level carriers, but data for third-level carriers (interstate air commuters) were derived from monthly records of commuter traffic at each of the airports having such service. The combined annual totals of all two-way air demand were then divided by 730 to yield average daily one-way demand. In the Northeast Corridor, data from the NECTP study were used directly.

Table B-16. California Corridor and Midwest Triangle Modal Demand

Arena	City-Pair	Average Daily Person Trips in Each Direction								
		1967								
		Auto		Air		Bus		Rail		Total Trips
		Trips	%M.S.	Trips	%M.S.	Trips	%M.S.	Trips	%M.S.	
California Corridor	Los Angeles/ San Francisco	7466	55.11	5725	42.26	252	1.86	104	.77	13547
	Los Angeles/ Sacramento	1349	63.36	700	32.88	59	2.77	21	.99	2129
	Los Angeles/ San Diego	25230	90.19	1067	3.81	1498	5.35	182	.65	27977
	San Francisco/ San Diego	813	54.36	643	43.01	39	2.63	-	-	1495
	San Francisco/ Sacramento	13800	95.48	101	.70	552	3.82	-	-	14453
	San Diego/ Sacramento	108	66.87	47	29.05	7	4.08	-	-	162
Midwest Triangle	Chicago/ Cleveland	860	61.42	467	33.36	55	3.93	18	1.29	1400
	Chicago/ Detroit	1982	69.54	652	22.88	172	6.04	44	1.54	2850
	Cleveland/ Detroit	1375	78.13	272	15.45	113	6.42	None	-	1760

M.S. = Modal Split

Table B-17. Northeast Corridor Modal Demand

City-Pair	Trip Purpose (1)	% of Total Trips	Average Daily Person Trips in Each Direction 1968								
			Auto		Air		Bus		Rail		Total
			Trips	%M.S.	Trips	%M.S.	Trips	%M.S.	Trips	%M.S.	Trips
Boston/ New York	Business	36.05	1229	39.78	1710	55.35	64	2.09	86	2.79	3090
	Non-Business	63.95	3816	69.60	894	16.31	535	9.76	237	4.33	5483
	Total		5064	58.73	2617	30.34	608	7.05	334	3.87	8623
Boston/ Philadelphia	Business										
	Non-Business										
	Total		560	51.63	464	42.72	42	3.88	19	1.77	1085
Boston/ Washington	Business	42.63	51	11.62	384	87.12	1	.33	4	.93	440
	Non-Business	57.37	197	33.24	344	58.09	35	5.85	17	2.82	593
	Total		249	24.04	728	70.39	37	3.55	21	2.02	1035
New York/ Philadelphia	Business										
	Non-Business										
	Total		14658	78.27	88	.47	589	3.15	3392	18.11	18727
New York/ Washington	Business	36.97	111	33.51	1735	52.35	120	3.63	348	10.51	3315
	Non-Business	63.03	3507	62.05	816	14.44	816	14.44	512	9.07	5651
	Total		4626	51.20	2565	28.39	949	10.50	894	9.90	9034
Philadelphia/ Washington	Business	34.76	1302	71.27	253	13.83	32	1.76	240	13.14	1827
	Non-Business	65.24	2871	83.69	61	1.78	193	5.62	306	8.91	3430
	Total		4179	78.74	314	5.91	245	4.63	569	10.72	5308

(1) "Totals" include trips for which purpose was not stated and are thus slightly larger than the sum of the business and non-business trips

MS. = Modal Split

(3) Bus and Rail Data

The major bus companies serving the arenas in this study were Greyhound Lines and Continental Trailways. These organizations did not have complete origin and destination (O&D) data for each city pair, but they did provide information on one-way and round-trip ticket sales for selected months of the year and on the ratio of monthly to yearly sales. An average daily demand figure was calculated from these data. In general, this information was available only for the past few years, so the data were plotted as a function of year and extrapolated to the calibration year. Rail data were similarly based on ticket sales in current years and extrapolated to the calibration year.

b. Total Travel Demand Projections

Following a review of existing demand forecast models, a gravity model (Ref. 41) was initially used to analyze intercity demand within the California Corridor. The model expressed intercity trips as a function of population product and intercity distance as follows:

$$\text{Number of Intercity Person-Trips} = \frac{(\text{Population Product})^{\alpha}}{(\text{Intercity Distance})^{\beta}} \qquad \text{(B-1)}$$

where α and β are calibrated to historical intercity trip data for all cities under consideration. The model was adjusted to fit a large number of city pairs, based primarily on a single calibration year. The comparison with actual traffic (Table B-18) showed errors as large as 75 percent in one case, and an average error of 32 percent. It was decided that the model could be improved by using data available from recent 1967 cordon surveys as well as the original 1960 data. A plot of daily person-trips for both years as a function of population product is shown in Figure B-11 for four city pairs in the California Corridor. According to the conventional gravity model approach, for any given intercity distance, the slope of the data on such a

Table B-18. Variation between Actual and Estimated Intercity Annual Two-Way Traffic within the California Corridor, 1960

City-Pair	Actual Traffic (thousands)	Estimated	Estimated as Percent of Actual Traffic
BAKERSFIELD - LOS ANGELES	8,819.0	9,499.3	107.7%
BAKERSFIELD - SAN DIEGO	137.3	154.1	112.2
FRESNO - LOS ANGELES	1,403.9	1,990.7	141.8
*LOS ANGELES - SACRAMENTO	867.3	648.9	74.8
*LOS ANGELES - SAN DIEGO	16,948.0	29,800.7	175.8
*LOS ANGELES - SAN FRANCISCO	6,714.3	4,449.3	66.3
*LOS ANGELES - SAN JOSE	1,083.4	1,310.3	120.9
LOS ANGELES - SANTA BARBARA	8,566.0	7,654.9	89.4
LOS ANGELES - STOCKTON	310.0	414.5	133.7
*SACRAMENTO - SAN DIEGO	46.3	35.4	76.5
*SACRAMENTO - SAN FRANCISCO	12,868.0	11,825.0	91.9
*SACRAMENTO - SAN JOSE	2,543.8	1,598.7	62.8
*SAN DIEGO - SAN FRANCISCO	416.7	238.5	57.2
*SAN DIEGO - SAN JOSE	46.7	64.5	138.1
SAN DIEGO - SANTA BARBARA	153.0	115.3	75.4
SAN DIEGO - STOCKTON	12.3	21.0	170.7

*City-Pairs included in California Corridor Arena for STOL Study

Source: Ref. 41

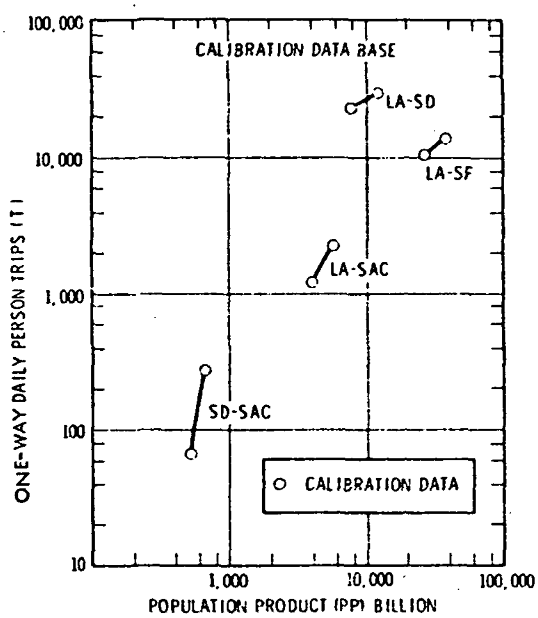

Figure B-11. Travel Demand Calibration Data Base

log-log plot should be a constant [the value α in Eq. (B-1)]. It is seen from the data that the slope is not a constant but decreases as the population product and the total number of daily person-trips increase. This is quite reasonable in that, as cities grow, the services available to any resident in his local area tend to increase; thus his need to travel to a distant city to satisfy his needs is lessened, resulting in a reduced rate of growth in intercity trips.

If the slope of the data segments shown in Figure B-11 is plotted as a function of total one-way daily person-trips, it is seen in Figure B-12 that a straight line results. Making use of this relationship, a series of curves can be constructed as shown in Figure B-13. The general equation for this set of curves is given by

$$T_1 = \left\{C[\log(PP_1) - \log(PP_0)] + T_0^K\right\}^{1/K} \qquad \text{(B-2)}$$

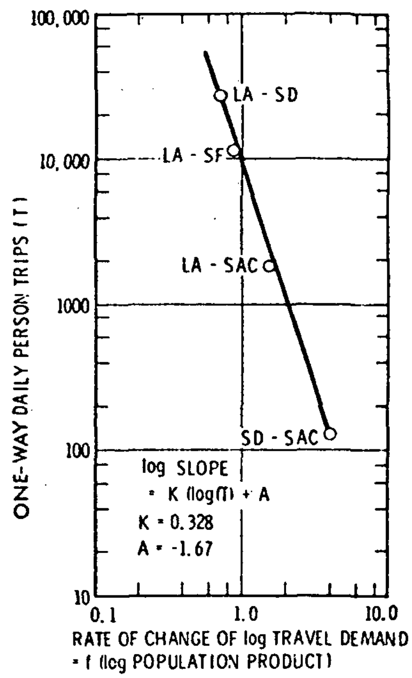

Figure B-12. Correlation between Rate of Change of Log Travel Demand and Level of Demand

where the calibration constant C is 15.3417 and K is 0.328, PP_0 is the survey data point population product, T_0 is the survey data point for daily person trips, PP_1 is the projected population product for the year of interest, and T_1 is the derived daily person-trips for the year of interest. Using these calibration constants, the fit to the California Corridor data was considerably better than the conventional gravity model, with errors generally under 10 percent for any city pair. Checks against limited-time series data for a few city pairs in the Midwest and Northeast Corridor were encouraging; therefore, Eq. (B-2) was chosen as the basis for 1980 total demand forecasting.

Unlike the gravity model of Eq. (B-1), Eq. (B-2) requires a single survey data point for each city pair investigated, where both the population product and the corresponding daily person-trips between the city pair are known. This effectively takes into account travel-demand factors for that pair which are unrelated to population alone (e.g., seats of government and tourist

- UNLIKE GRAVITY MODEL REQUIRES SINGLE SURVEY DATA POINT FOR EACH CITY PAIR INVESTIGATED
- ALL NON-POPULATION TRAVEL DEMAND FACTORS ASSUMED TO BE ACCOUNTED FOR IN SURVEY DATA POINT
- SUBSEQUENT CHANGES IN TRAVEL DEMAND, RELATIVE TO SURVEY DATA POINT, RELATED TO POPULATION GROWTH

$$T_1 = \left(C\left(\log\left(PP_1\right) - \log\left(PP_0\right)\right) + T_0^{K}\right)^{1/K}$$

WHERE: THE CALIBRATION CONSTANTS $C = 15.3417$ AND $K = 0.328$

AND PP_0 = SURVEY DATA POINT POPULATION PRODUCT

T_0 = SURVEY DATA POINT DAILY PERSON TRIPS

PP_1 = PROJECTED POPULATION PRODUCT FOR YEAR OF INTEREST

T_1 = DERIVED DAILY PERSON TRIPS FOR YEAR OF INTEREST

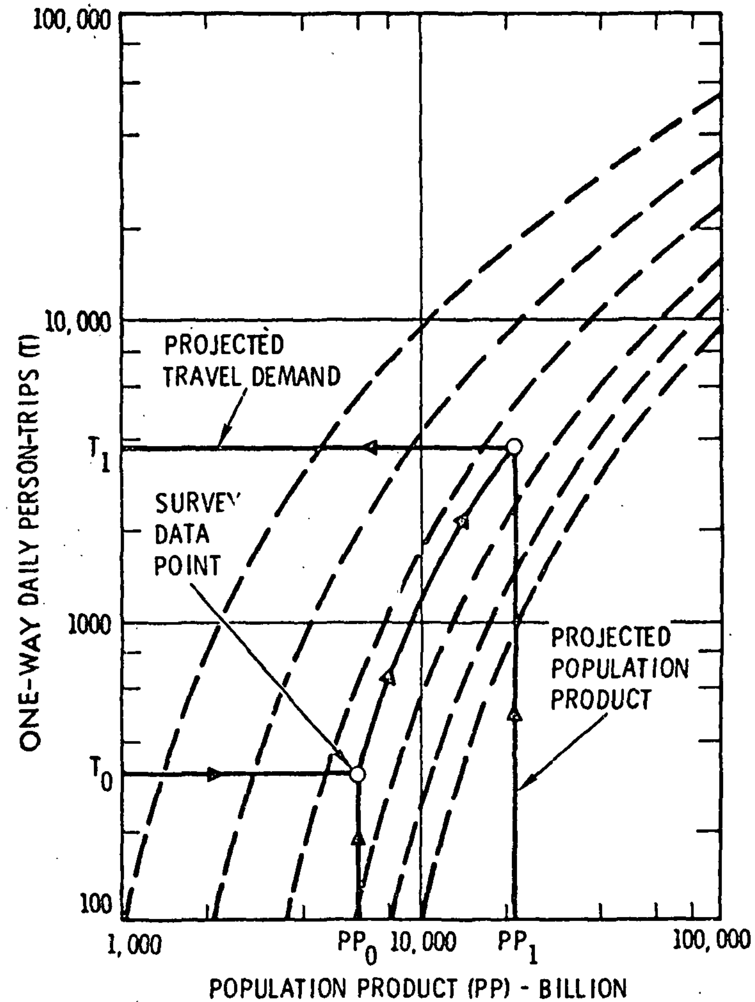

Figure B-13. Intercity Travel Demand Model

attractions). City pairs which generate a large demand would be expected to have a calibration point on one of the upper curves, while those with relatively less attraction would yield a calibration point on the lower curves. To develop potential demand for some future time period, the only other information needed is the forecasted population product.

The relationship represented by Eq. (B-2) was used to forecast 1980 travel demand between each city pair considered in this study. The population data for the calibration year were obtained from regional planning agencies, and the corresponding intercity travel demand developed by summing auto, CTOL, rail, and bus trips for each city pair. Populations for the 1980 forecast year were either obtained directly from these same regional planning agencies, or extrapolated using census data. Population products were then formed and used in Eq. (B-2) to develop demand forecasts. A summary of the data inputs and resulting demand projections by city pair is presented in Table B-19.

c. <u>Projected Service Characteristics</u>

The modes modeled for 1980 were car, CTOL, bus, and rail – Specific trip time, cost, and frequency values were developed for each port-to-port path within each city pair. The resulting service path characteristics for the California Corridor, Midwest Triangle, and Northeast Corridor are shown in Tables B-20, B-21, and B-22, respectively. The costs and times listed for car are intercity values between pseudo ports generally located on the periphery of a region and, as a result, are less than the city-center-to-city-center values. Except for rail, alternative modes were assumed to have the same characteristics in 1980 as in 1971/72. Since all costs were expressed in 1970 dollars, this assumption is equivalent to assuming that cost increases during the 1970 to 1980 time period are equal to the rate of inflation. Similarly, it was assumed that the transportation equipment for these modes would not change significantly during this period, and thus the travel times would not change. Assumptions and techniques used in developing specific modal characteristics are discussed in succeeding paragraphs.

Table B-19. Total Intercity Travel Demand Forecasts

Arena	City-Pair	Population Product (X 10^9)		Average Daily Person Trips in Each Direction	
		1967	1980	1967	1980
California Corridor	Los Angeles/ San Francisco	38316	56697	13547	18890
	Los Angeles/ Sacramento	5640	7714	2129	3427
	Los Angeles/ San Diego	11551	18398	27977	38235
	San Francisco/ San Diego	5117	8178	1495	3204
	San Francisco/ Sacramento	2499	3429	14453	18852
	San Diego/ Sacramento	753	1113	162	547
Midwest Triangle	Chicago/ Cleveland	13700	16600	1400	2000
	Chicago/ Detroit	27500	35000	2850	4050
	Cleveland/ Detroit	8230	9700	1760	2300
		1968	1980	1968	1980
Northeast Corridor	Boston/ New York	65359	84345	8623	11119
	Boston/ Philadelphia	17880	23138	1085	1767
	Boston/ Washington	9778	16227	1035	2562
	New York/ Philadelphia	80748	110270	18727	23840
	New York/ Washington	44159	77335	9034	15282
	Philadelphia/ Washington	12080	21215	5308	9859

Table B-20. California Service Path Characteristics

Mode	Service Path	Cost ($)	Time (hr)	Frequency (no. departures/hr)
Los Angeles-San Francisco				
CAR	LGOR-FSJ	12.32	5.65	-
	LSFV-FSJ	13.80	6.26	-
	LOXN-FSJ	12.76	6.08	-
CTOL	LLAX-FSFO	16.50	1.0	2.43
	LLAX-FSJC	16.50	0.83	0.72
	LLAX-FOAK	16.50	0.92	0.75
	LBUR-FSFO	16.50	0.83	0.57
	LBUR-FSJC	16.50	0.75	0.50
	LBUR-FOAK	16.50	1.17	0.50
	LONT-FSFO	18.00	1.03	0.50
	LONT-FSJC	21.60	0.92	0.36
	LONT-FOAK	21.60	1.32	0.29
	LSNA-FSFO	21.60	1.0	0.43
	LSNA-FSJC	21.60	0.92	0.43
	LSNA-FOAK	21.60	1.0	0.50
	LLGB-FSFO	18.00	1.03	0.43
BUS	LCBD-FCBD	13.50	9.0	1.35
RAIL	LCBD-FCBD	16.00	10.67	0.07
Los Angeles-Sacramento				
CAR	LSFV-SCBD	14.24	6.20	-
	LSFV-SGALT	13.32	5.82	-
CTOL	LLAX-SSMF	18.00	1.0	1.07
	LBUR-SSMF	21.00	1.53	0.36
BUS	LCBD-SCBD	12.50	9.58	0.77
Los Angeles-San Diego				
CAR	LSNA-DOCN	2.00	0.82	-
	LSNA-DCBD	3.52	1.40	-
	LRIV-DCBD	3.88	2.0	-
	LRIV-DRIV	2.04	1.07	-
	LCAP-DOCN	1.04	0.42	-
	LCAP-DCBD	2.56	1.0	-

*1970 dollars

Table B-20. California Service Path Characteristics (continued)

Mode	Service Path	Cost ($)	Time (hr)	Frequency (no. departures/hr)
CTOL	LLAX-DSAN	8.29	0.50	1.80
	LBUR-DSAN	8.00	0.50	0.40
	LSNA-DSAN	8.00	0.42	0.47
BUS	LCBD-DCBD	4.36	2.5	1.38
	LCBD-DOCN	3.38	1.75	1.38
	LLGB-DCBD	3.84	2.25	0.54
	LSNA-DCBD	3.49	1.90	0.69
	LSB-DCBD	4.89	2.33	0.54
RAIL	LCBD-DCBD	4.75	2.75	0.20
	San Diego-Sacramento			
CAR	DOCN-SCBD	18.56	8.02	∞
	DOCN-SGALT	17.64	7.63	∞
	DCBD-SCBD	20.12	8.62	∞
	DCBD-SGALT	19.20	8.23	∞
CTOL	DSAN-SSMF(a)	25.00	1.67	0.13
	DSAN-SSMF(b)	27.00	2.47	0.37
BUS	DCBD-SCBD	16.80	13.00	0.47
	San Francisco-San Diego			
CAR	FSJ -DOCN	18.12	8.08	∞
	FSJ -DCBD	19.68	8.68	∞
CTOL	FSFO-DSAN	24.50	1.29	0.62
	FSJC-DSAN	24.50	1.58	0.92
	FOAK-DSAN	24.50	1.85	1.23
BUS	FCBD-DCBD	17.40	13.00	0.69

(a) Direct flight
(b) Connecting flight

Table B-20. California Service Path Characteristics (continued)

Mode	Service Path	Cost ($)	Time (hr)	Frequency (no. departures/hr)
San Francisco-Sacramento				
CAR	FVAL-SCBD	2.30	1.07	
	FVAL-SDAV	1.60	0.68	
	FDAV-SCBD	0.68	0.30	
	FDAV-SDAV	0.0	0.0	
CTOL	FSFO-SSMF	8.00	0.55	0.43
	FSJC-SSMF	12.00	0.58	0.14
BUS	FCBD-SCBD	3.84	2.20	1.78
	FOAK-SCBD	3.48	1.80	1.78
	FSJ-SCBD	4.33	4.75	0.29
	FWOD-SCBD	0.85	0.42	0.36

Table B-21. Midwest Triangle Service Path Characteristics*

Mode	Service Path	Cost ($)	Time (hr)	Frequency departures/hr)
Chicago-Detroit				
CAR	CCHI-DCHL	9.56	3.77	∞
CTOL	COHARE-DMETRO	27.00	0.92	1.17
	CMDWAY-DMETRO	27.00	0.92	0.57
	CMIEGS-DCITY	30.00	1.25	0.29
BUS	CCBD-DCBD	12.70	5.55	0.64
RAIL	CCBD-DCBD	16.25	5.50	0.14
Chicago-Cleveland				
CAR	CCHI-VAMH	17.00	4.07	∞
	CCHI-VLOR	11.67	6.17	∞
CTOL	COHARE-VHOPKN	33.00	1.11	0.89
	CMDWAY-VHOPKN	33.00	1.00	0.29
BUS	CCBD-VCBD	15.55	7.5	0.79
RAIL	CCBD-VCBD	19.75	6.6	0.07
Detroit-Cleveland				
CAR	DROC-VAMH	5.48	1.76	∞
	DTOL-VAMH	4.20	1.27	∞
CTOL	DMETRO-VHOPKN	18.00	0.58	0.82
	DCITY-VBURKE	22.00	0.67	1.00
BUS	DCBD-VCBD	8.25	3.15	0.715

* Costs and times are port-to-port, not door-to-door (see Figures B-8 through B-10 for port locations).

Table B-22. Northeast Corridor Service Path Characteristics

Mode	Service Path	Cost ($)	Time (hr)	Frequency (departures/hr)
		Boston - New York		
CAR	BOS1 - NYC2	6.66	2.81	∞
	BOS1 - NYC3	7.67	2.94	∞
	BOS1 - NYC4	5.57	2.28	∞
	BOS2 - NYC3	8.48	3.31	∞
	BOS2 - NYC4	6.38	2.67	∞
	BOS3 - NYC2	8.22	3.26	∞
	BOS3 - NYC3	9.23	3.35	∞
	BOS3 - NYC4	7.13	2.67	∞
CTOL	BOS - JFK	22.25	.95	1.14
	BOS - LGA	22.25	.83	2.20
	BOS - EWR	22.25	.93	1.32
	BOS - HPN	25.96	.75	.5
	BOS - BDR	21.32	.70	.21
	BOS - ISP	23.18	.75	.36
BUS	BOSB - PABT	9.25	4.5	2.84
	BOSB - GWBT	9.25	4.08	1.14
	BOSB - BRIB	7.18	3.55	.55
	BOSB - WPB	8.16	4.60	.45
	NEWT - PABT	9.25	4.17	2.28
	NEWT - GWBT	9.25	3.75	.92
	NEWT - BRIB	7.18	3.55	.55
	NEWT - WPB	8.16	4.27	.45
RAIL	BOSR - PENN	15.95	2.95	1.35
	BOSR - STAM	13.90	2.50	.92
	BOSR - EWRR	16.80	3.40	1.14
	BOSR - METR	17.78	3.50	.57
	128R - PENN	15.95	2.70	1.35
	128R - STAM	13.90	2.28	.92
	128R - EWRR	16.80	3.20	1.14
	128R - METR	17.78	3.30	.57

Table B-22. Northeast Corridor Service Path Characteristics (continued)

Mode	Service Path	Cost ($)	Time (hr)	Frequency (departures/hr)
New York - Washington				
CAR	NYC1 - WAS1	9.89	3.08	∞
	NYC1 - WAS2	10.17	3.21	∞
CTOL	JFK - DCA	24.10	1.08	.79
	JFK - IAD	24.10	1.25	.28
	LGA - DCA	24.10	1.02	2.34
	LGA - IAD	24.10	1.00	.43
	EWR - DCA	24.10	1.00	1.28
	EWR - IAD	24.10	1.15	.53
	HPN - DCA	30.59	.95	.50
	BDR - DCA	32.45	1.50	.21
	ISP - DCA	26.88	.90	.36
BUS	PABT -WASB	10.95	4.05	2.62
	PABT -LAUB	10.95	4.30	.63
	EWRB-WASB	10.95	3.95	.45
	BRUN - WASB	10.02	3.60	.27
RAIL	PENN -WASR	15.95	2.35	2.10
	PENN -BELT		2.20	1.00
	EWRR-WASR	15.30	2.15	1.21
	EWRR-BELT	15.05	2.00	.72
	STAM -WASR	18.30	3.30	1.13
	STAM - BELT	17.85	3.15	.56
	METR -WASR	14.37	2.05	.71
	METR-BELT	13.92	1.90	.36
Philadelphia - Washington				
CAR	PHL1 - WAS1	5.52	1.66	∞
	PHL1 - WAS2	5.80	1.79	∞
	PHL3 - WAS1	7.72	2.18	∞
	PHL3 - WAS2	8.00	2.30	∞
CTOL	PHL - DCA	19.47	.67	1.14
	PHL - IAD	19.47	.87	.21
BUS	PHLB - WASB	6.40	3.3	2.0
	MORB - WASB	6.40	3.0	.45
	CHSB - WASB	6.40	2.7	.55
RAIL	PHLR - WASR	10.20	1.48	1.55
	PHLR - BELT	9.75	1.33	.65

Table B-22. Northeast Corridor Service Path Characteristics (continued)

Mode	Service Path	Cost ($)	Time (hr)	Frequency (departures/hr)
Boston - Philadelphia				
CAR	BOS1 - PHL2	13.04	5.16	∞
	BOS1 - PHL3	14.23	5.55	∞
	BOS2 - PHL2	14.16	5.63	∞
	BOS2 - PHL3	15.35	6.02	∞
	BOS3 - PHL2	14.60	5.61	∞
	BOS3 - PHL3	15.79	6.00	∞
CTOL	BOS - PHL	28.74	1.00	1.71
BUS	BOSB - PHLB	14.37	7.5	1.0
	NEWT - PHLB	14.37	7.2	1.0
RAIL	BOSR - PHLR	21.92	4.00	.92
	BOSR - TTNR	20.15	3.60	.86
Boston - Washington				
CAR	BOS1 - WAS1	21.95	7.9	∞
	BOS1 - WAS2	22.23	8.03	∞
	BOS2 - WAS1	23.61	8.37	∞
	BOS2 - WAS2	23.89	8.49	∞
	BOS3 - WAS1	23.51	8.35	∞
	BOS3 - WAS2	23.79	8.47	∞
CTOL	BOS - DCA	35.23	1.23	1.78
	BOS - IAD	35.23	1.45	.21
BUS	BOSB - WASB	20.90	9.5	1.08
RAIL	BOSR - WASR	30.20	5.40	1.35
	BOSR - BELT	29.75	5.20	.86
	128R - WASR	30.20	5.15	1.35
	128R - BELT	29.75	4.95	.86

(1) Car

Automobile travel between major cities in the 1980 time period was assumed to be similar to 1971/72 conditions. New major highways or throughways projected for completion by 1980 were accounted for, otherwise the existing highway system was adopted for 1980 modeling purposes. Whenever possible, automobile travel times predicted by regional highway agencies, such as the Departments of Highways for the various states involved, were used in this study. The American Automobile Association was also used as a source of trip-time data as well as a source of toll information. In a few instances where trip times were not available for some highway segments, they were based on the average automobile speed appropriate to the region and highway type being considered (e.g., two-lane, divided, etc.). Car travel was modeled as a relatively high-speed portion between the outskirts of the cities and a relatively low-speed "local travel" portion within the more densely populated areas of the cities. Likely "auto ports" were located at the outskirts of each city, and car time was computed as the sum of the low-speed portion of the trip within the cities to or from their outskirts and the high-speed portion between the outskirts. As previously noted, the car times shown in Tables B-21 and B-22 only reflect the high-speed or port-to-port portion of the trip. In the modal split program, the low-speed, door-to-port or port-to-door trip segments are accounted for by use of city-peculiar travel functions. Auto travel costs were based on mile age traveled (4 cents per mile) and tolls. As noted previously, this is a perceived cost which excludes such fixed costs as insurance and depreciation. Recent gasoline shortages and price increases tend to make this a somewhat optimistic assumption, and would result in an air modal split which is less than that which might actually be achieved. In all instances where a multiple choice of candidate intercity routes was available to the auto traveler, the faster routes were generally the more expensive (due to tolls). In any case, all of the candidate auto routes a traveler would most likely consider, both fast and slow, were included for analysis in this study.

(2) Conventional Takeoff/Landing Aircraft

The CTOL environment forecast for 1980 was substantially similar to 1971/72 conditions. No increase in congestion for either air traffic control or at CTOL ports was forecast. This forecast is based upon assumption of an increase in the average size of CTOL aircraft utilized in CTOL service. This includes the replacement of 100-passenger DC9-30 aircraft with 150-passenger B727-200 aircraft on the Eastern Air Shuttle, and the partial replacement of PSA's 158-passenger B727-200 aircraft with 289-passenger L1011-1 aircraft on the Los Angeles/San Francisco service path. The 1980 CTOL frequency levels and trip times on all major service paths are those existing in 1971 or 1972 (Ref. 42). Fares (including tax) were 1971 coach fares for the California Corridor and Midwest Triangle. Mid-1972 coach fares were used for the Northeast Corridor, converted to 1970 dollars by the Consumer Price Index. In order to verify that these fares would be applicable in the 1980 time period, an analysis was made comparing a current 727-200 aircraft (158 passengers) with a hypothetical 1980 CTOL design (250 passengers). The latter vehicle assumed costlier noise-suppression techniques (comparable to a DC-10), but reflected some cost benefits due to larger capacity and use of composite materials. DOCs, IOCs, ROI, cost per departure, and break-even fare per passenger were computed for both vehicles over a range of distances and load factors. In all cases the break-even fare per passenger was slightly less for the 727 than for the 1980 CTOL design. It was therefore concluded that the assumption of current CTOL fares for the 1980 time period (in 1970 dollars) was a conservative one, with respect to STOL system viability.

(3) Bus

The bus mode for 1980 was modeled by using 1971/72 trip times and frequencies and by converting these bus fares to 1970 dollars. An effort was made to reflect the ability of the bus mode to serve suburban as well as central city ports. For this reason some city pairs were modeled with as many as eight bus service paths.

(4) Rail

For the Midwest and California arenas, rail modes for 1980 were modeled with the same characteristics as for 1971. For certain city pairs in these arenas, rail was not modeled at all, since there was no service in 1971 nor any indication of any new service to be provided. In the NEC, the rail service path characteristics were based on a projected Interim High Speed Rail System (IHSR-1). This IHSR-1 was taken from the NEC Transportation Report (Ref. 38) and included trip times for the trains providing nonstop service between major city pairs.

The number of IHSR-1 daily trains for 1980 was determined by applying the ratio (forecast 1980 rail passengers divided by the number of 1971 rail passengers) to the number of trains scheduled between Boston/New York and New York/Washington in 1971. A schedule of station stops was developed for each train. From this schedule, total trips for each rail service path were derived. Final trip times for each train were computed by adding time for each additional station stop to the nonstop times.

The fares were based on the cost formula for the IHSR-1 with added IOC elements for advertising, publicity, and passenger ticket commissions which were excluded from the reference cost formula. The resulting cost formula (in 1970 dollars) for Cost (C) in cents per revenue passenger mile was:

$$C = 4.01 + \frac{38.75}{P} + \frac{0.196/\text{Pass} + 0.005/\text{ASM} + 0.0234/\text{Pass. Rev}}{\text{RPM}}$$

P = NEC rail passengers in millions (12.98)
RPM = Revenue passenger miles
ASM = Available seat miles
Pass = Number of passengers
Pass. Rev = Passenger revenue

The cost formula produced a required system average fare of 7.46 cents/RPM, which was converted to a constant $1 per passenger plus $0.0658/mile, to calculate the 1980 fares (in 1970 dollars) for the IHSR-1 between each NEC city pair.

B.5 DATA SOURCES

The references listed below represent the major data sources used in developing previously discussed demographic and socioeconomic characteristics of each arena, mode service features, and travel demand between city pairs. The complete file of reports, letters, interview notes, etc. is too large to be listed herein.

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VOLUME II

APPENDIX C

TRANSPORTATION SYSTEM SIMULATION

CONTENTS

		Page No.
C. 1.	STOL System Definition	C-3
C. 2.	Modal Split Program	C-17
	a. Arena Characterization	C-18
	b. Input Data	C-19
	c. Gneration of Traveler Attributes	C-24
	d. Cost Function Computations	C-25
	e. Mode Choice	C-26
	f. Outputs	C-26
	g. Model Calibration	C-27
	h. Zonal Characteristics	C-30
	i. Diurnal Distribution of Desired Departure Times	C-34
	j. Demand-Matching Routing	C-35

FIGURES

C-1.	Transportation Systems Simulation Approach	C-3
C-2.	Intercity Total Daily Travel Demand	C-4
C-3.	Application of Modal Split Program, etc.	C-4
C-4.	Application of Economic Analysis	C-6
C-5.	Example of Arena Aggregation	C-10
C-6.	Port-Related IOC Program	C-11
C-7.	Example of Port-Related IOC Determination Process	C-12
C-8.	Sensitivity of Port-Related IOCs to Vehicle Capacity and ROI, California Corridor	C-13
C-9.	Sensitivity of Port-Related IOCs to Vehicle Capacity and ROI, Midwest Triangle	C-14
C-10.	Sensitivity of Port-Related IOCs to Vehicle Capacity and ROI, Northeast Corridor	C-14
C-11.	STOL Patronage, California Corridor	C-16
C-12.	STOL Patronage, Midwest Triangle	C-16
C-13.	STOL Patronage, Northeast Corridor	C-17
C-14.	Elements of Modal Split Simulation Model	C-18

FIGURES (continued)

		Page No.
C-15.	Derivation of Zonal Travel Propensities and Traveler Income	C-32
C-16.	Diurnal Distribution of Desired Departure Times	C-36

TABLES

C-1.	System Definition Process	C-5
C-2.	System Definition Process	C-7
C-3.	Example of Service Path Selection Process	C-8
C-4.	System Definition Process Summary	C-8
C-5.	System Definition Process with Estimated Port-Related IOCs	C-11
C-6.	Completed System Definition Process	C-15
C-7.	California Corridor Preference Factor Medians	C-29
C-8.	Midwest Triangle Preference Factor Medians	C-29
C-9.	Northeast Corridor Preference Factor Medians.	C-29

APPENDIX C

TRANSPORTATION SYSTEM SIMULATION

This study was conducted with the aid of an Aerospace-developed Transportation System Simulation (TSS). This simulation, a combination of computer programs and off-line operations, was structured to determine STOL system characteristics — including schedules, fares, route structure, and noise buffer zone requirements — so as to:

- Maximize patronage
- Attain noise compatibility in the terminal area
- Achieve a stipulated return on investment.

As a prerequisite to deriving the STOL operator's ROI, the appropriate fleet size, revenues, operating costs, profits, investment costs, and STOL system-induced STOLport capital costs were also determined. The latter include site acquisition, airfield and terminal construction or expansion, and the creation of noise buffer zones, and were:

- Initially incurred by the airport operator
- Passed back to the STOL operator in the form of higher landing fees and/or terminal rentals
- Grouped with station operating costs as port-related indirect operating costs (IOCs).

This feedback feature of the simulation made it possible to identify and evaluate the economic impact of different noise alleviating options:

- The use of quieter but perhaps more costly aircraft
- The relocation of STOLports to areas less sensitive to noise but further from the centers of demand
- The inclusion of additional STOLports serving the same region in order to diffuse the demand, number of operations, and resulting noise levels at any one port

- The creation of noise buffer zones with the resulting increase in indirect operating costs.

This version of the TSS required that the arena (i.e., a group of city pairs), the STOL aircraft configuration, and the desired ROI (used as a criterion for STOL system economic viability) be established as input quantities. The quantities were treated parametrically, with an optimum set of STOL system characteristics defined by the TSS for each specified combination. These input sets were made up of all possible combinations of three arenas (California Corridor, Midwest Triangle, and Northeast Corridor), 16 STOL aircraft configurations (2,000-foot augmentor wing concept ranging in size from 50 to 200 passengers in increments of 10), and four ROI levels.

The problem was bounded by several constraints, including:

- Maximum average load factor on any one service path limited to 65 percent
- A minimum of four round trips per day per STOL service path
- A common fare for STOL service between a given city pair, independent of individual service path characteristics.

In the event that the specified ROI could not be attained for a given city pair, that city pair would be deemed nonviable and was subsequently excluded from the STOL system defined for that arena.

The balance of this section is divided into two parts: The first part, Section C-1, describes the sequential interaction and integration of the TSS components leading to a STOL system definition. Examples of the input and output parameters are used to illustrate the progressive narrowing of the number of variables until ultimately — for any one combination of arena, vehicle size, and desired ROI — those schedules, fares, routes, city-pairs, and noise buffer zone requirements that maximize STOL patronage while satisfying the study constraints are identified. The second part, Section C-2, describes the modal-split simulation approach, perhaps the most unique component of the TSS methodology.

C. 1 STOL SYSTEM DEFINITION

The process leading to STOL system definition is illustrated by the flow diagram of Figure C-1 starting with the modeling of each arena for the 1980 time period with respect to demographic, economic, and transportation system characteristics. Projections of 1980 intercity travel demand were

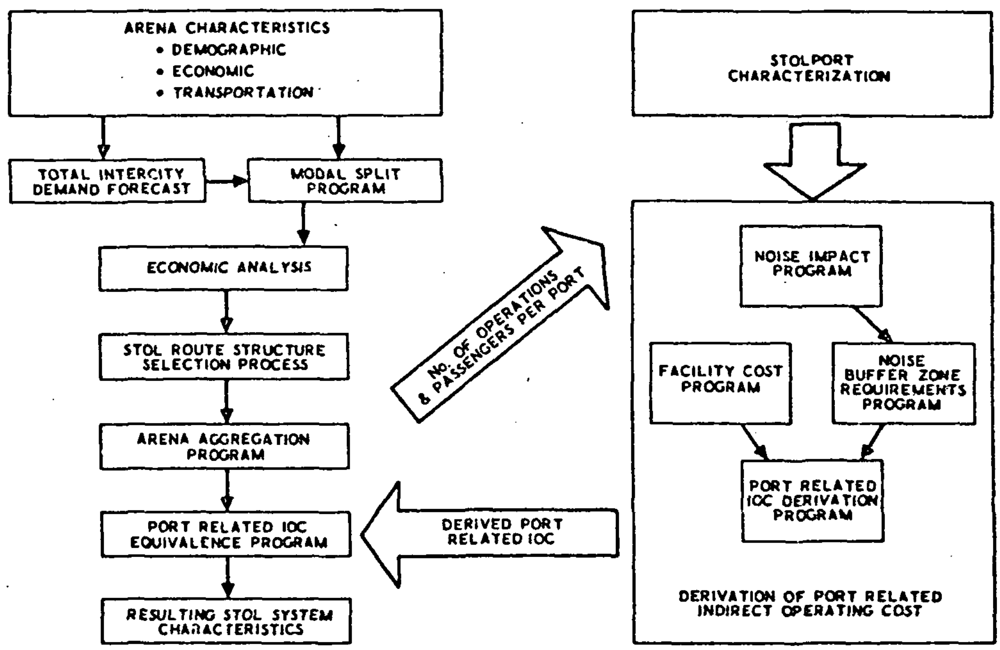


Figure C-1. Transportation Systems Simulation Approach

derived for each of the 14 city pairs examined in this study (methodology described in Appendix B. 4. b). The resulting demand levels are shown in Figure C-2. The modal split simulation was then utilized to determine STOL patronage for each city pair as a function of schedules, fares, route structure, and a preliminary estimate of port-related IOCs. An example of the modal split results is presented in Figure C-3, which displays the variation of STOL demand (average number of person trips per day) on each of three service paths as a function of frequency of service (number of round trips per day)

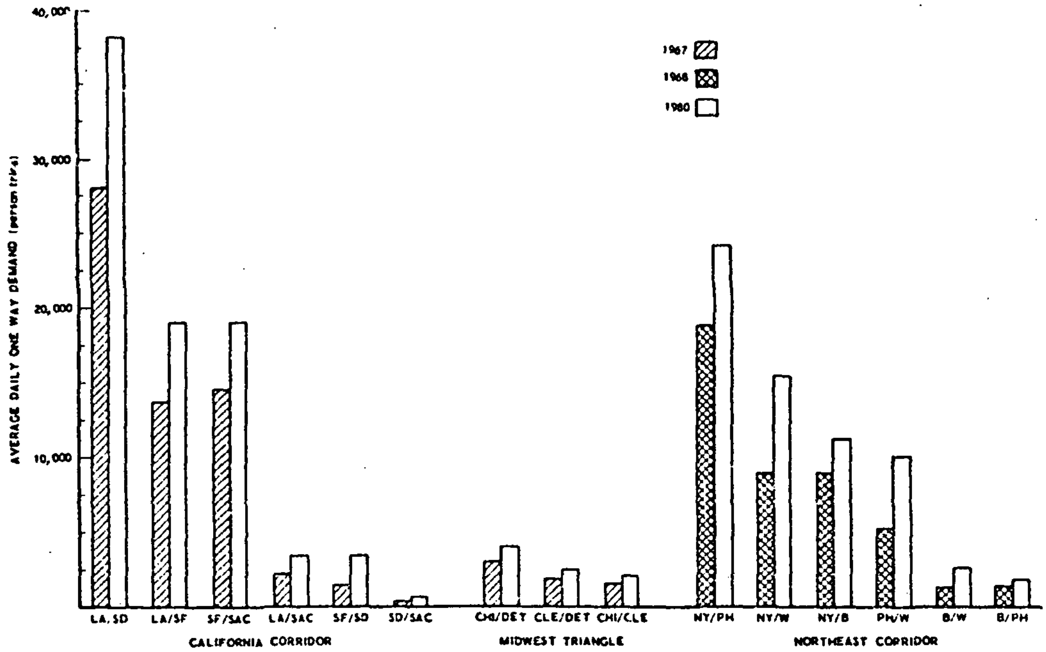


Figure C-2. Intercity Total Daily Travel Demand

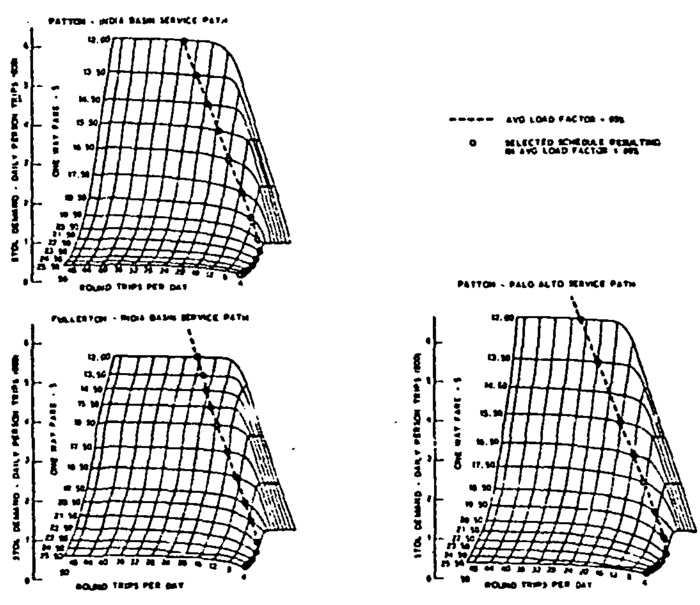


Figure C-3. Application of Modal Split Program; Los Angeles/San Francisco City Pair 3-Service-Path Set; 150-Passenger Aircraft, Port-Related IOC = $165/Departure

and one-way fare for a given combination of vehicle size, city-pair, route structure, and estimated port-related IOC. As shown in Figure C-3 for each of the postulated fares, demand is known as a function of number of round trips (i.e., available seats). This relationship permits the computation of the average load factor on each service path for each combination of fare and frequency of service. These data were used to determine that frequency of service that will produce an average load factor of 65 percent. Hence, in this manner, a frequency of service is established for each combination of the remaining variables that will either produce a 65-percent average load factor on each service path or, if that level is not attainable, produce the maximum average load factor compatible with the minimum frequency of service (four round trips per day). The status of this process after the application of the total demand and modal split programs is summarized in Table C-1.

Table C-1. System Definition Process

Input Variable (No. of Values)	Programs Used to Determine Sensitivity	Resulting STOL System Characteristics Determined for Each Combination of Remaining Variables	Remaining Parametric Variables
Schedules (20/path)	Total Intercity Demand Modal Split	Schedules Fleet Size Demand Average Load Factor	Fares Service Path Sets City Pairs Estimated Port-Related IOCs

Up to this point, demand was determined without considering economic viability of the STOL system. To ascertain the ROI, an economic analysis is performed that is associated with each combination of remaining variables and corresponding selected schedules. This procedure involves aggregating the demand and operations of each individual service path that serves the same city pair at common fares. The schedule requirement together with the block time, turnaround time, and postulated aircraft utilization

dictated the fleet-size requirement. Vehicle flyaway cost and fleet size were then used to estimate total investment costs, including aircraft, spares, and ground equipment. Revenues were determined as the product of fare less tax (8%) and patronage. Profits were then determined based on revenues and operating costs, including the estimated value of port-related IOC.

At this point, a sufficient data base had been developed to permit the derivation of ROI. An example of the results produced by the economic analysis is illustrated in Figure C-4, where ROI is plotted as a function of fare for a given set of vehicle size, city pair, route structure, and port-related IOC.

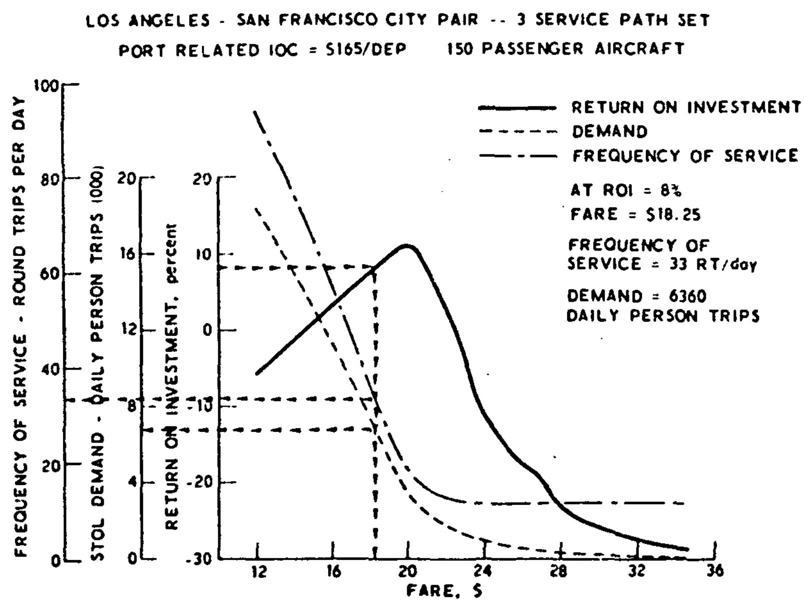


Figure C-4. Application of Economic Analysis

In this example, although an ROI of 11 percent is possible, the desired ROI was established at 8 percent, resulting in a fare of $18.25 which produced an average daily demand of 6360 person-trips served by 33 round trips per day. Thus, combining the economic analysis procedure with a pre-established ROI goal identified a fare, investment cost, revenue, operating cost, and profit set for each of the remaining variables as summarized in Table C-2.

Table C-2. System Definition Process

Input Variable (No. of Values)	Programs Used to Determine Sensitivity	Resulting STOL System Characteristics Determined for Each Combination of Remaining Variables	Remaining Parametric Variables
Schedules (20/path)	Total Intercity Demand Modal Split	Schedules Fleet Size Demand Average Load Factor	
Fares (20/city-pair)	Economic Analysis	Fare Investment Costs* Revenues Operating Costs Profits ROI	Service Path Sets City-Pairs Estimated Port-Related IOCs

*Excluding port related IOC.

The criterion for route selection is to maximize patronage while achieving the desired ROI. An example of the inputs to this selection process is presented in Table C-3. Four service-path sets containing 1, 3, 6, and 8 service paths, respectively, were examined. While total STOL patronage increased with an increasing number of service paths, the average demand per individual service path decreased, which in turn influenced the maximum attainable ROI. In the example shown in Table C-3, the three-service-path set was finally selected, since it produced the greatest patronage while achieving the desired ROI of 8 percent. Table C-4 summarizes the results of the TSS approach through the application of the service path selection process.

The process described in the preceding paragraphs of Section C-1 was repeated for each city pair postulated for a given arena. The resulting demand, schedules, and economic parameters were subsequently aggregated for common values of estimated port-related IOCs. City pairs that did not attain the desired ROI were excluded from the arena aggregation. Primary results of the arena-aggregation program were the determination of the level of traffic, both in terms of passengers and in aircraft operations, at each STOLport in the system. The necessity for this step is apparent when it is

Table C-3. Example of Service Path Selection Process

LOS ANGELES - SAN FRANCISCO

150 PASSENGER AIRCRAFT DESIRED ROI = 8%

PORT RELATED IOC = $165/DEP

No. OF STOL SERVICE PATHS	SERVICE PATHS	DEMAND DAILY PERSON TRIPS	ROI, %
1	PATTON - INDIA BASIN	4373	8
3	PATTON - INDIA BASIN FULLERTON - INDIA BASIN PATTON - PALO ALTO	6303	8
6	PATTON - INDIA BASIN FULLERTON - INDIA BASIN PATTON - PALO ALTO PATTON - CONCORD BUCHANAN TRI CITIES - INDIA BASIN FULLERTON - PALO ALTO	7138	7.58*
8	PATTON - INDIA BASIN FULLERTON - INDIA BASIN PATTON - PALO ALTO PATTON - CONCORD BUCHANAN TRI CITIES - INDIA BASIN FULLERTON - PALO ALTO VAN NUYS - INDIA BASIN VAN NUYS - PALO ALTO	8019	5.82*

*Maximum attainable ROI

Table C-4. System Definition Process Summary

Input Variable (No. of Values)	Programs Used to Determine Sensitivity	Resulting STOL System Characteristics Determined *for Each Combination* of Remaining Variables	*Remaining Parametric* Variables
Schedules (20/path)	Total Intercity Demand Modal Split	Schedules Fleet Size Demand Average Load Factor	
Fares (20/city pair)	Economic Analysis	Fare Investment Costs Revenues Operating Costs* Profits ROI	
STOL Service Path Sets	STOL Route Selection Process	STOL Route Structure	City Pairs Estimated Port-Related IOCs

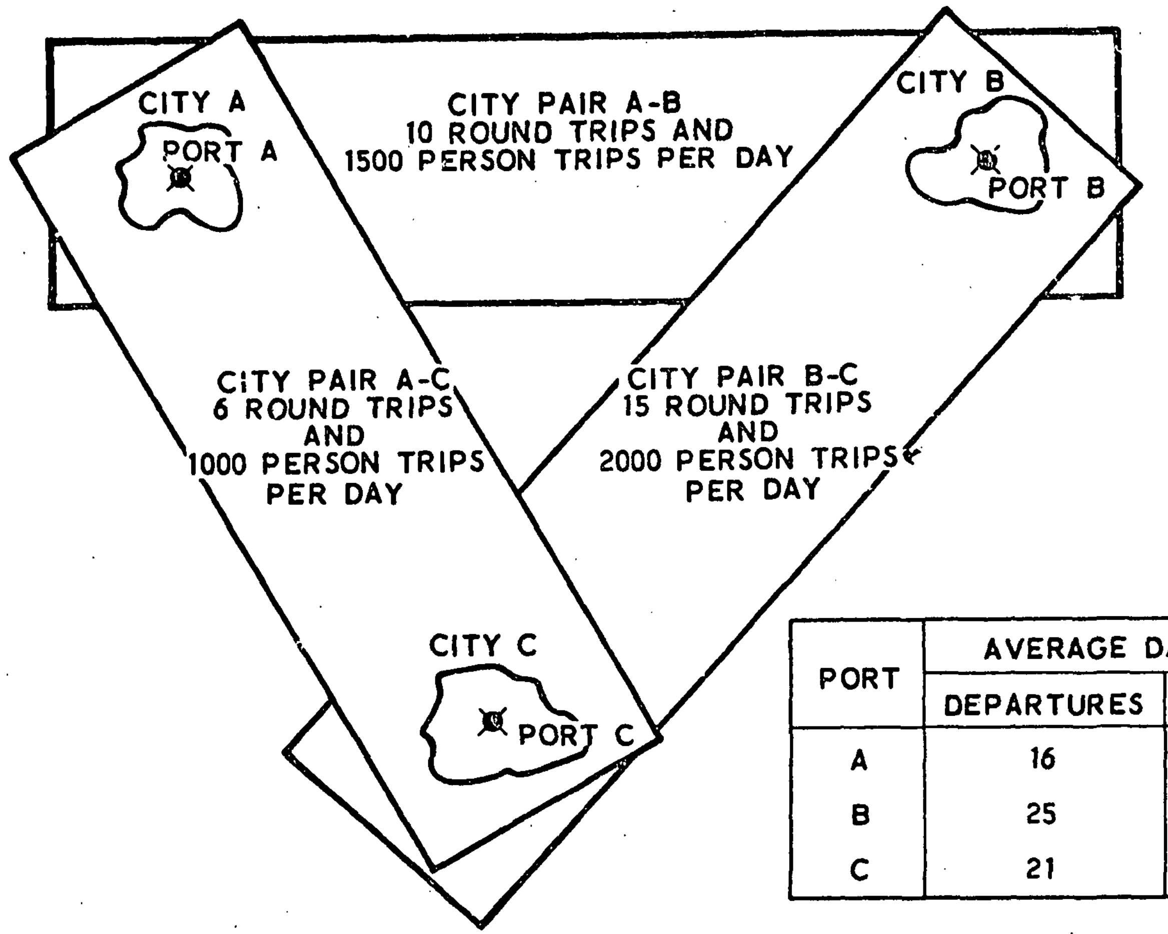
*Excluding port related IOC

recognized that a given STOLport may be common to service paths serving more than a single city pair. A conceptual example of this process is illustrated in Figure C-5.

The number of STOL operations and volume of the O&D passenger traffic identified for each STOLport in the system were then used as input parameters in computing the derived (as opposed to the estimated) port-related IOC (as described in Appendix A.3.d). The elements contributing to this derivation are illustrated in the flow diagram of Figure C-6. STOL-induced airport operating costs include such items as facility maintenance and crash, fire, and rescue operations. In addition to the costs required to create noise buffer zones, the STOLport capital costs accounted for site requisition, and the expansion or creation of terminal buildings, gates, apron, runways, and taxiways as required to support the projected level of a 1980 STOL service that uses aircraft with a specified weight and landing gear configuration. Navigation aids and facilities such as restaurants and parking lots were not included in the STOLport capital costs, since it was assumed that these items would not be ultimately charged to the STOL operator. Air-carrier and station operating costs included those incurred for passenger and baggage handling, aircraft handling, depreciation and ground equipment maintenance, and lease hold improvements.

STOLport capital costs were amortized and combined with the airport operating costs in order to determine the level of terminal rental and landing fee revenue required to support the STOL-induced airport costs. These sources of airport revenue were combined with the air-carrier station operating costs to determine the annual port-related IOCs which, for the given annual number of STOL operations, were then converted into a derived port-related IOC per departure.

Thus, as shown in Table C-5, after applying the arena aggregation and port-related IOC derivation programs, all that remained to be done was to establish an equivalence between the estimated and derived values of the port-related IOCs. This was accomplished by comparing the derived with the estimated values, as illustrated by the example of Figure C-7, and determining the point where equivalence is achieved.



PORT	AVERAGE DAILY TRAFFIC	
	DEPARTURES	O&D PASSENGERS
A	16	2500
B	25	3500
C	21	3000

Figure C-5. Example of Arena Aggregation
3 City Pairs with Single STOLport in Each City

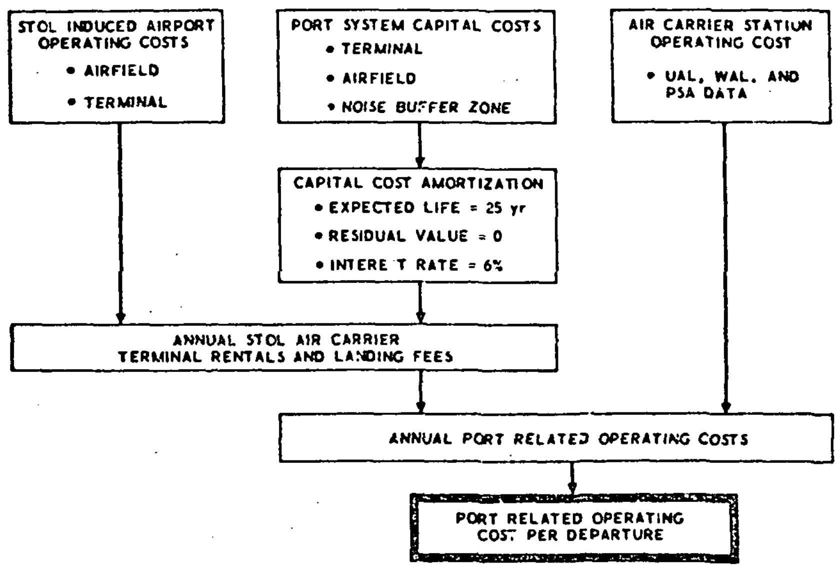


Figure C-6. Port-Related IOC Program

Table C-5. System Definition Process with Estimated Port-Related IOCs

Input Variable (No. of Values)	Programs Used to Determine Sensitivity	Resulting STOL System Characteristics Determined for Each Combination of Remaining Variables	Remaining Parametric Variables
Schedules (20/path)	Total Intercity Demand Modal Split	Schedules Fleet Size Demand Average Load Factor	
Fares (20/city-pair)	Economic Analysis	Fare Investment Costs Revenues Operating Costs* Profits ROI	
STOL Service Path Sets	STOL Route Selection Process	STOL Route Structure	
City-Pairs	Arena Aggregation Port-Related IOCs Derivation Process	STOL Activity Derived Port-Related IOCs Economically Viable City Pairs	Estimated Port- Related Related IOCs

*Excluding port-related IOCs

Higher estimated port-related IOCs would, for fixed DOCs, result in higher fares, lower demand, and fewer operations. Fewer operations would reduce noise buffer requirements and costs at a rate directly related to the noise level of the study aircraft. For quiet aircraft, noise buffer zone costs would be relatively insensitive, both to the number of operations and to the parameters influencing the number of operations, including estimated port-related noise buffer zone costs. The insensitivities of derived values to estimated values, shown in Figure C-7, are attributable to the low noise level of the study aircraft. Its negligible noise impact results in virtually no change in buffer zone requirements as the number of operations changes. The derived port-related IOCs would become greater and the slope (Figure C-7) progressively more negative as STOL aircraft noise levels were increased. This would

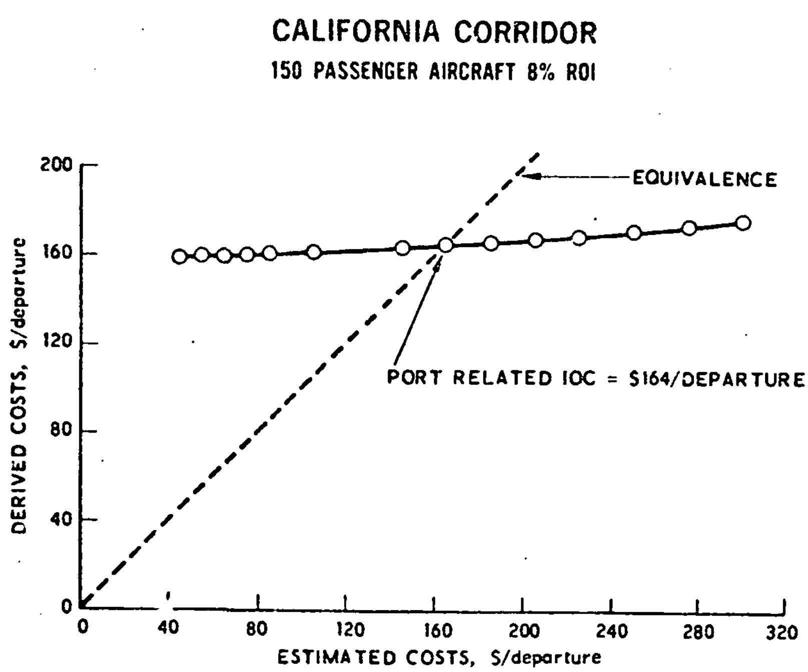


Figure C-7. Example of Port-Related IOC Determination Process

move the crossover point to the right resulting in a higher port-related IOC, and (assuming a constant DOC) would necessitate a higher fare for a given ROI, which in turn would reduce STOL patronage and thereby adversely affect STOL system viability.

The variation of port-related IOCs that produced equivalence (derived value equal to estimated value) as a function of desired ROI and vehicle size is shown in Figures C-8 through C-10 for each of the three arenas, respectively. Sensitivity to aircraft size can be attributed to passenger-handling expense, which can be approximated by a constant cost-per-passenger; the variation with respect to ROI reflects the amortization of fixed costs (such as runway construction costs) over the resulting number of operations.

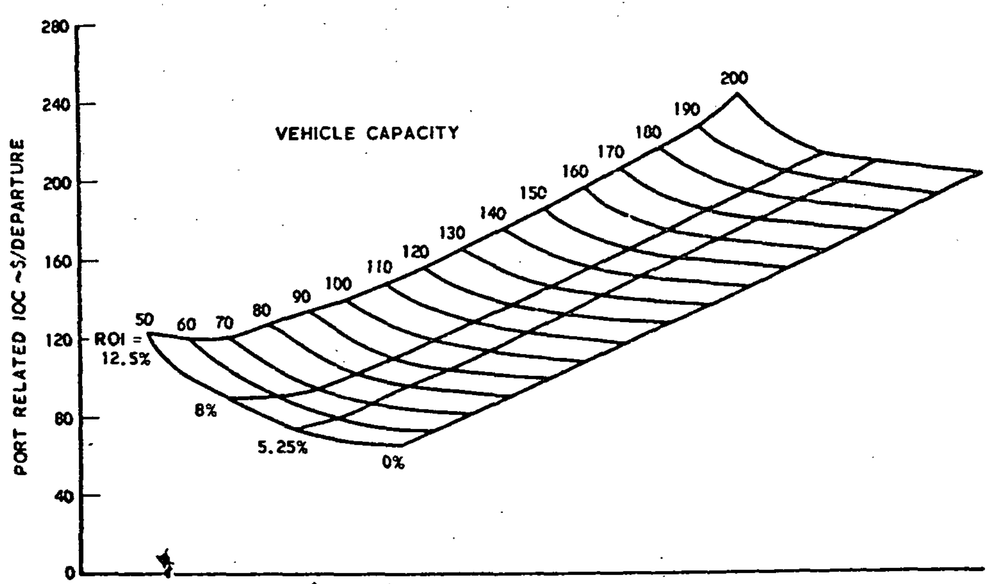


Figure C-8. Sensitivity of Port-Related IOCs to Vehicle Capacity and ROI, California Corridor

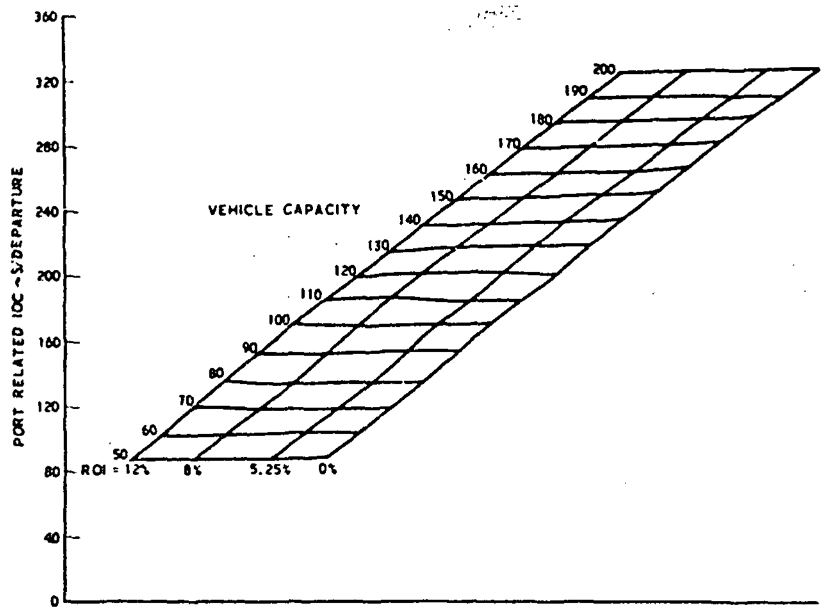


Figure C-9. Sensitivity of Port-Related IOCs to Vehicle Capacity and ROI, Midwest Triangle

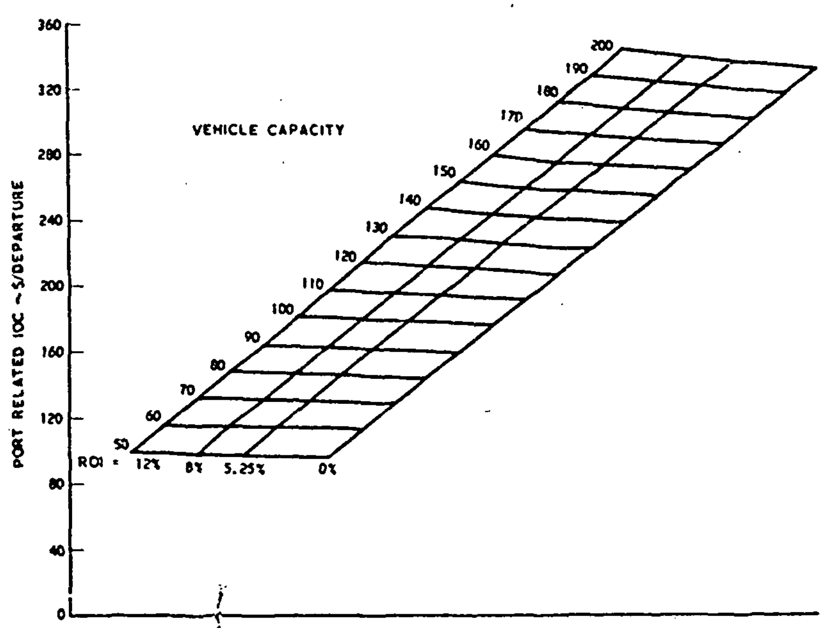


Figure C-10. Sensitivity of Port-Related IOCs to Vehicle Capacity and ROI, Northeast Corridor

Once equivalence was obtained, it was then possible to define the single set of STOL system characteristics as described in Table C-6. This process was repeated for each of the remaining combinations of arenas, vehicle size, and ROI. The resulting data base was utilized to identify a variety of system characteristics, as a function of vehicle size and ROI, for each of the three arenas. The variation of STOL patronage, presented in Figures C-11 through C-13, is an example of the sensitivities that can be extracted from this data base.

Table C-6. Completed System Definition Process

Input Variable (No. of Values)	Programs Used to Determine Sensitivity	Resulting STOL System Characteristics Determined for Each Combination of Remaining Variables
Schedules (20/path)	Total Intercity Demand Modal Split	Schedules Fleet Size Demand Average Load Factor
Fares (20/city pair)	Economic Analysis	Fare Investment Costs Revenues Operating Costs* Profits ROI
STOL Service Path Sets	STOL Route Selection Process	STOL Route Structure
City Pairs	Arena Aggregation Port-Related IOCs Derivation Process	STOLport Activity Derived Port-Related IOCs Economically Viable City Pairs
Estimated Port-Related IOCs (15/arena)	Port-Related IOCs Equivalenced	Port-Related IOC STOL-Induced Port Modifications Noise-Buffer-Zone Requirements

*Excluding port-related IOC

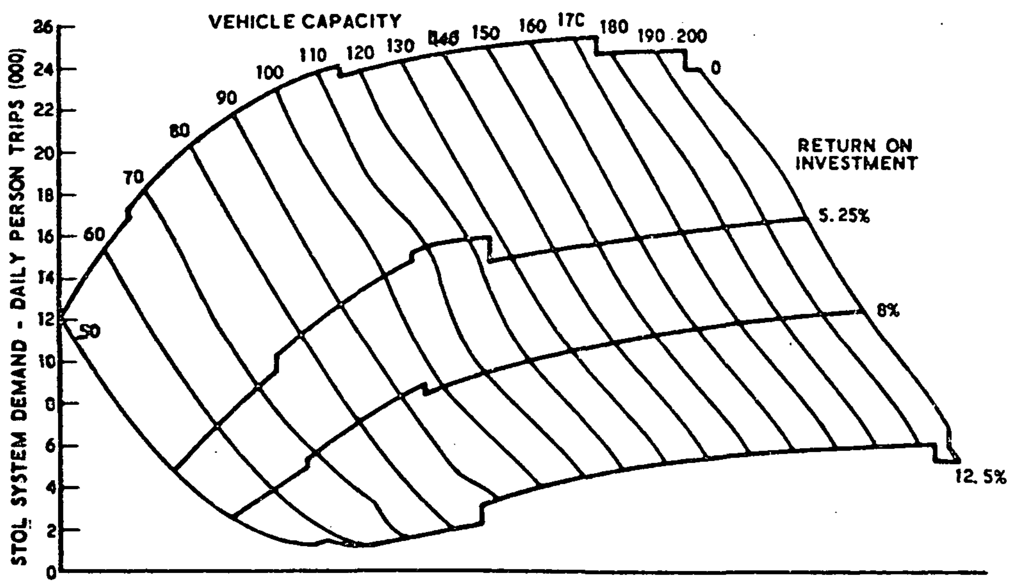


Figure C-11. STOL Patronage, California Corridor

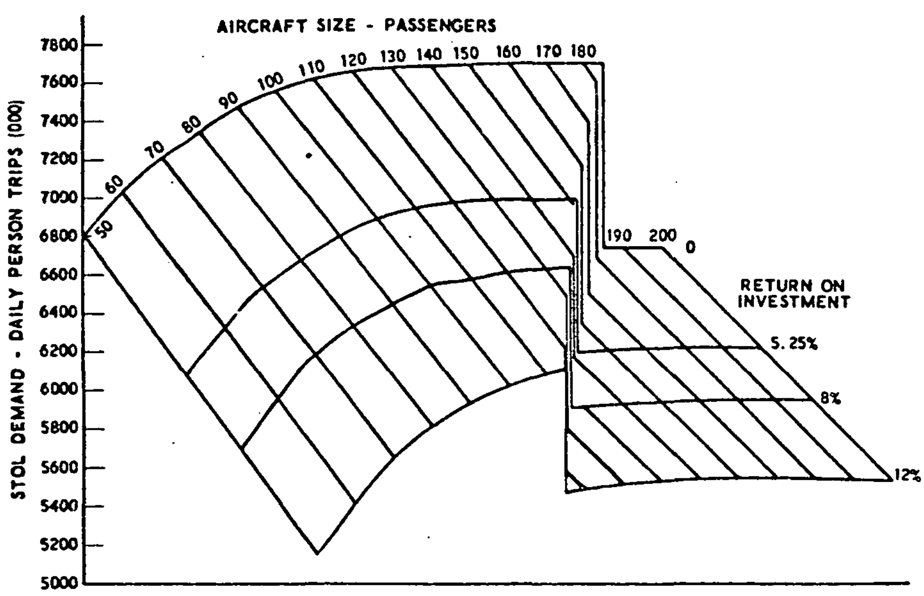


Figure C-12. STOL Patronage, Midwest Triangle

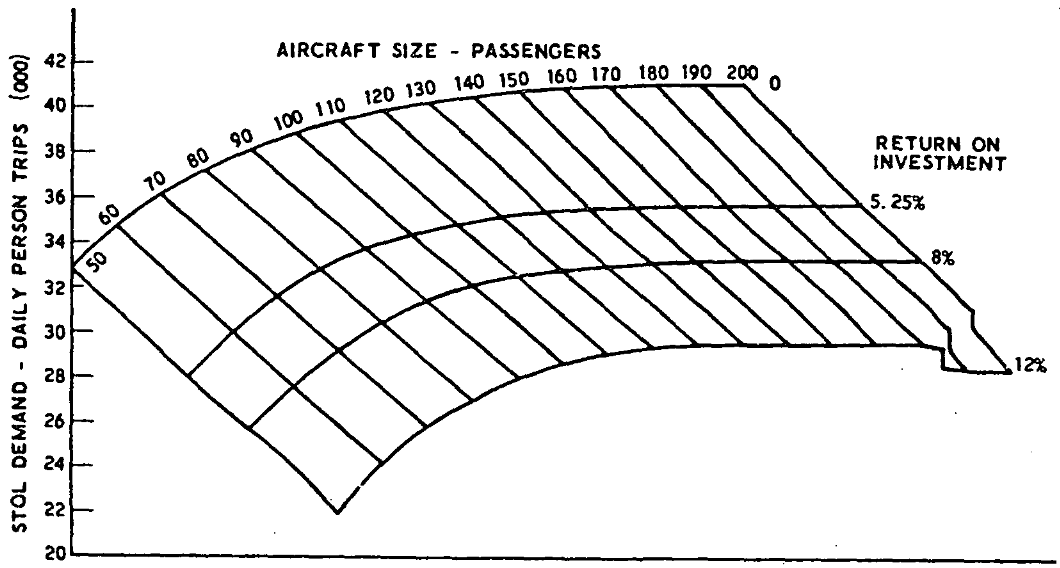


Figure C-13. STOL Patronage, Northeast Corridor

C.2 MODAL SPLIT PROGRAM

Modal split analysis estimates the utilization of a number of alternative travel modes between specified origins and destinations. The method described herein computes the modal split by generating simulated travelers, each having a set of pertinent attributes randomly selected from appropriate probability distributions. Distributions are used to determine the purpose and duration of trip, origin and destination, door locations and time of day, the traveler's "time value" (a function of his income) and party size, his "preference factor" for each alternative travel mode, and his waiting times (functions of service frequency) for each mode. (These quantities are explained fully in Appendix B.) The attributes of individual simulated travelers are generated by drawing random samples from these distributions.

Once an individual traveler's attributes have been generated, his "effective cost function" for each travel mode is computed. This effective

cost function reflects out-of-pocket cost, trip time, travel mode service frequency, and traveler preferences. When the effective cost functions for the alternative modes have been computed, the traveler is assigned to the mode which produced the minimum effective cost function.

One mode (designated as the special mode, i.e., STOL in this particular analysis) is treated differently with respect to frequency of service. For this mode, it is assumed that there is infinite frequency of service or, in effect, no waiting. Instead, when a traveler is assigned to STOL, a computation is made to determine how long he will be willing to wait before taking an alternate mode. The modal split and a distribution of maximum STOL waiting time is thus determined by generating many simulated travelers and assigning each traveler to his minimum cost function mode. The information will be used later in the demand-matching routine which uses specific STOL schedules. This routine is discussed in Appendix C. 2. j.

a. Arena Characterization

Figure C-14 depicts the arena as an abstraction of the real world in which the modal-split simulation takes place. Each of two regions is divided

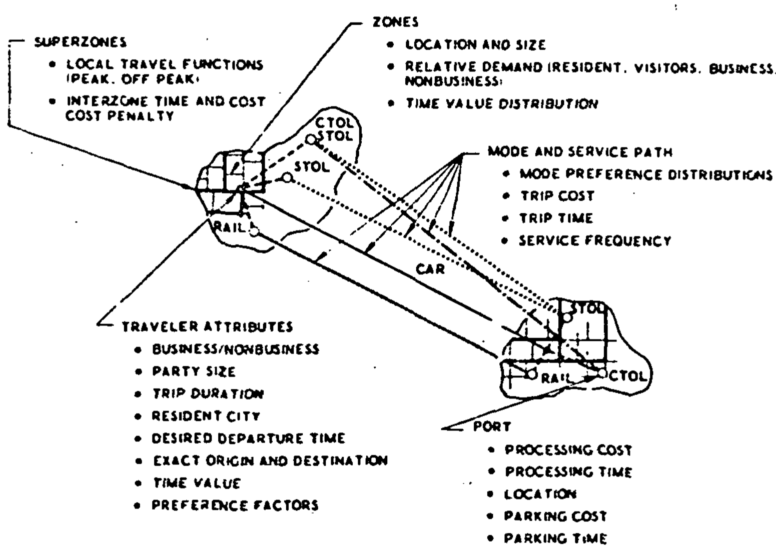


Figure C-14. Elements of Modal Split Simulation Model

into sets of superzones, with each superzone so defined as to have common local travel characteristics and no internal travel barriers or constrictions. Each superzone consists of a number of rectangular zones typically conforming to zonal divisions established by local planning agencies. Each travel mode has one or more ports in each city, some of which may be co-located (as, for example, combined CTOL and STOL airports). The car mode is also considered to have "ports," normally representing points of access to the highway system between the two regions. Transportation service may be provided between some or all intercity port pairs. Each port pair of each mode for which service is provided is called a service path. Service, when provided, is characterized by its cost, trip time, and frequency (car mode is always considered to have infinite service frequency).

b. Input Data

(1) Arena Inputs

Inputs associated with the entire simulation arena consist of:

- The number of simulated travelers to be generated in order to get a statistically accurate modal split
- The fraction of those travelers that are business travelers
- The relative number of travelers that live in each city
- The party size and trip duration distributions for both business and nonbusiness travelers
- The fraction of travelers affected by frequency of service
- A factor which expresses the conversion of waiting time to perceived time.

The specified service frequencies of the various modes (expressed as the number of departures per hour) are used to compute the time intervals between departures. For those travelers who are affected by service frequency, random samples are drawn from these time intervals during simulation and are used to compute waiting times for the various modes. These waiting times are then converted to their equivalent perceived times. Waiting

time may be perceived to be worse than traveling time if the waiting is done at a port or station. On the other hand, if waiting is done at home or at the office, this may be time effectively spent, and the delay would not consist of totally wasted time.

The distinction between business and nonbusiness travelers is important because many of the attributes directly affecting mode choice are dependent upon whether or not the traveler is on a business trip (for example, the traveler's time value, trip duration, and party size). Party size is important because certain direct costs (for example, the parking cost at a port) are shared by the travel party as a whole. The trip-duration distributions (found to be inherently log-normal) are represented by two parameters related to the median and standard deviation of a log-normal distribution. The fraction of travelers of a given type (business or nonbusiness) affected by frequency of service represent those who have strong schedule preferences; much of the time they spend waiting at either end of a flight or trip is wasted. Conversely, the fraction not affected by service frequency represents those flexible travelers who would not be appreciably inconvenienced even if a mode had only a few departures during the simulation interval.

Note that, with the exception of the waiting time conversion factor and the number of travelers to be simulated, all of the input quantities discussed in this section represent distributions and, as such, they are not utilized directly in subsequent computations. Rather, random samples drawn from these distributions are used to establish the attributes of individual simulated travelers.

(2) Regional Inputs

Inputs associated with each region consist of the fraction of trips arriving or departing during the peak traffic period of the day and a diurnal STOL demand distribution. Tables are also provided of parking cost and transportation rental cost versus trip duration for the destination region. These tables permit different costs to be incurred in the destination region, depending upon whether a traveler drives there (in which case he would incur

parking costs) or takes a public transportation mode (in which case he would incur local transportation expenses). Either or both of these costs may be made zero for all values of trip duration if appropriate for a specific application.

(3) Superzone Inputs

Superzone inputs consist of local travel functions and interzone time and cost penalties.

Superzones formed from the region as a whole are based on three criteria: First, all zones in a superzone should be contiguous. Furthermore, within a superzone there should not be significant barriers to local travel, such as large bodies of water or other constraints which restrict the free flow of traffic. Finally, the area within the superzone should be reasonably homogeneous relative to local-travel speed profiles.

Each superzone can have up to two car local-travel functions (for peak and off-peak traffic periods) and up to four other local travel functions (two for peak and two for off-peak). These functions are in the form of cost versus distance and time versus distance tables. The tables permit computations of cost and time associated with door-to-port (origin region) and port-to-door (destination region) portions of trips to be based on the distance to be traveled. The tables further enable each simulated traveler to make a trade-off between driving his car and parking at the port (for his trip duration) versus taking one of the other local transportation modes (which may include kiss and ride, taxi, local bus, airport limousine, etc., or a composite of these). The tables permit realistic nonlinearities in these functions, such as the fact that, for short distances, local travel is accomplished at a lower average speed than for longer distances. Travelers who use the car for their port-to-port mode must use the car tables for local travel in each region. Travelers using noncar modes must use noncar transportation in the destination region, but may choose the most cost-effective door-to-port mode in the origin region.

If a traveler's origin or destination is in a superzone other than that of the port he is considering, the total local distance is divided by two, and

the local tables from each of the two superzones involved are used to obtain a composite time and cost. Furthermore, two time penalties (for peak and offpeak) and one cost penalty may be uniquely assigned to travel between pairs of superzones.

- The time penalties can be used to represent bottlenecks (such as tunnels, bridges, and mountain passes) or to represent the additional time required to go around rather than through barriers.
- The cost penalty may be used to represent tolls.

Thus, in general, local tra· . between a door and port is made up of two time-and-cost versus distan... elements (one for each superzone involved) and an interzone time-and-cost penalty.

(4) Zonal Inputs

The inputs associated with each rectangular zone of a city are:

- The coordinates of the corners of the zone (relative to an arbitrary origin)
- The relative resident business travel demand (the number of resident business travelers emanating from that zone relative to other zones)
- The relative visiting business travel demand (the number of nonresident business travelers arriving in that zone relative to other zones).
- The relative resident nonbusiness travel demand (the number of resident nonbusiness travelers emanating from that zone relative to other zones)
- The relative visiting nonbusiness travel demand (the number of nonresident nonbusiness travelers arriving in that zone relative to other zones)
- The car unavailability factor for business and nonbusiness travelers
- The lognormal time value distributions for business and non-business travelers.

Time value is the hourly rate a traveler associates with the time spent on his trip, and it is generally considered to vary depending upon whether he is traveling for business or for nonbusiness purposes. Time value

is used to convert total trip time to equivalent dollar cost. The provision for separate time value distributions for each zone permits a realistic representation of the variations in affluence throughout the region.

(5) Modal Inputs

Each travel mode has an associated lognormal preference-factor distribution for both business and nonbusiness travelers. The preference factors for the various modes are intended to represent all of the non-economic factors affecting mode choice (that is, all of the factors which cannot be expressed in units of cost and/or time). Since they represent the intangibles, the preference factors are the calibration parameters of the simulation model. They are the quantities that are adjusted to achieve consistency between model predictions and actual mode-use surveys in arenas for which survey data exist. In the simulation, the intercity portion of a traveler's cost function for each mode is divided by his preference factor for that mode (as drawn from the appropriate distribution). Thus, a preference factor of less than 1 for a given mode indicates that the traveler views that mode with disfavor, whereas a factor greater than 1 indicates a preference for the mode. Preference factors, therefore, represent the degree to which a traveler will go against pure time-cost factors in choosing a travel mode. The calibration process will be described in detail later.

(6) Port Inputs

Each travel mode may have one or more ports in each region. Ports are uniquely associated with specific modes. For example, a combined CTOL/STOL port is simulated by locating a CTOLport and a STOLport at the same point. Each port is characterized by its location (coordinates and superzone), processing cost, peak and off-peak processing time, parking time, and a table of parking cost versus trip duration (the length of time in days that the traveler will be away from his resident city). The port processing cost is simply any cost incidental to the use of that port, such as a baggage handling

charge. The processing time is the time spent from arrival at the entrance to the port until the intercity portion of the trip begins. This time might typically include baggage checking, intraport movement, ticketing, and lead time. However, it does not include waiting, which is treated separately. The parking time is the additional time required to park a car and walk from the parking lot to the port entrance. This time is added if the traveler elects to drive his car to the port and park it for the trip duration. The parking-cost table is used to establish the cost he incurs.

(7) Service Path Inputs

The inputs associated with each service path are those required to describe the service provided between that pair of ports: out-of-pocket cost, trip time, and service frequency. For public transportation modes, the out-of-pocket cost is the fare, the trip time is the scheduled time (which may include an increment for predictable or usual delay), and the service frequency is the number of trips made per hour. For car mode, cost and time are the values that apply to that service path, and service frequency is not input since it is automatically considered to be infinite (a traveler's own car, if available, is not constrained by a finite "service frequency"). Similarly, the special mode (STOL) is initially considered to have infinite frequency, since explicit schedules for this mode will be modeled later in the Demand-Matching routine (Appendix C.2.j).

c. Generation of Traveler Attributes

The attributes of each simulated traveler are generated by random draws from input-probability distributions. Correlations between attributes are explicitly represented in that the determination of a given attribute may define the distributions from which other attributes are drawn.

The sequence used to generate a complete set of attributes for a simulated traveler is as follows:

- First, a draw is made based on the number of travelers who live in each region to determine the traveler's resident region. This is the region in which his trip is assumed to originate.

- Departure and arrival time periods (peak or not-peak) are drawn, based upon the appropriate fractions for each region.
- A draw is made based on the specified fraction of travelers that are business travelers to determine the traveler's trip purpose.
- Based on the outcome, draws are made from the appropriate distributions to determine the traveler's origin-region zone, trip duration, party size, preference factors for each of the alternative modes, and destination region zone.
- From distributions associated with the traveler's origin zone, his time value, car availability, and origin-door, coordinates are drawn (door coordinates are drawn uniformly from within the zone).
- A determination of whether or not the traveler is affected by service frequency is made by drawing from the appropriate two-valued distribution representing the fraction of business or non-business travelers affected.
- If he is found to be affected, his waiting times for all the alternative service paths are computed by drawing from uniform distributions over the intervals between trips. For example, if the interval between trips on a particular service path is 30 minutes, the waiting time for that path will be determined by drawing from a uniform distribution of 0 to 30 minutes.
- Finally, the traveler's destination door coordinates are drawn from a uniform distribution over the destination zone.

d. <u>Cost Function Computations</u>

Once the attributes of a simulated traveler have been generated, his cost function for every service path is computed. The cost function for a given service path consists of three components: the door-to-origin-port portion of the trip, the port-to-port portion, and the destination-port-to-door portion. For each component, the pertinent costs and times are summed separately, and the total time is converted to equivalent cost by multiplying it by the traveler's time value. The port-to-port portion of the cost function [cost + (time) (time value)] is divided by the traveler's preference factor for the mode under consideration. All costs associated with the use of a private car (either for the entire trip, or driving to a port and parking) are divided by the traveler's party size. For public intercity modes, a tradeoff is made

between driving to the origin port and parking for the trip duration versus taking any of the other modeled local transportation modes to the port; the traveler is presumed to follow the course of action which results in the minimum cost function. Local travel (door-to-door and port-to-door) is presumed to take place along orthogonal north-south and east-west lines (or any other designated orthogonal compass directions for that matter), and local travel distances are computed accordingly. The assumption that local travel takes place along orthogonal lines represents a first-order model of a city street network while avoiding the necessity of representing such a network explicitly. If the local travel portion of the trip crosses any superzone boundaries, the appropriate time and cost penalties are added.

e. Mode Choice

Each simulated traveler is assigned to that mode and service path having the smallest effective-cost function. If this mode is the special mode (STOL), an additional computation must be made to determine the traveler's maximum tolerable waiting time for this mode. A traveler's willingness to wait for a STOL flight is measured by the difference between the STOL effective-cost function and the effective-cost function of the next-best non-STOL mode. This difference, expressed in dollars, is converted into waiting time using the traveler's sampled time value and waiting time factor. If the traveler had to wait more than this length of time for a STOL flight, it is assumed that he would rather take the next-best mode (which already has its waiting time taken into account in its cost function).

f. Outputs

The outputs of the modal split simulation program consist of optional output during simulation and a standard set of outputs at the conclusion of a simulation. During simulation, "traveler's records" may be printed for every nth traveler (where n is specified). A traveler's record consists of all of the known facts about a given traveler: all of his attributes, his assignment to a particular mode and service path, and the cost function components (all the costs and times) associated with that assignment. Traveler's records are

useful for verifying that a simulation case is specified correctly and for gaining insight into why travelers are making certain mode choices.

At the conclusion of a simulation, the number or fraction of travelers assigned to each service path of each travel mode is provided along with totals by city ports and travel modes. In addition, for the special mode, two waiting-time distributions are provided for each service path (one for each of the two time periods) along with the relative amount of travel on this mode during the two time periods. This special mode output is used as an input to the demand-matching program.

g. Model Calibration

One of the inputs to the modal split simulation model consists of a lognormal preference factor distribution for each travel mode. These distributions effectively serve to calibrate traveler preferences for the specific trips, modes, and regions being modeled.

Preference factors take into account qualitative aspects of a traveler's decision, which are not reflected in a pure cost-time tradeoff. For example, an air traveler may attach a certain amount of importance to the prestige and comforts of flying. A certain car traveler may feel that the scenic stops along the way compensate to a certain extent for the extra time involved. However, another traveler may think only of the problems associated with having a car in a strange city and, therefore, shy away from this mode. Some travelers take a train simply because they like to ride on trains.

In order to determine preference-factor distributions for each mode and each city pair, modal-split data for some base year are needed. Using such data, an iterative procedure is undertaken to determine preference factor distributions which produce modal-split results corresponding to the actual base-year modal splits. In the iterative calibration process, the program tries two initial sets of preference factor medians. Then, based on the errors between the simulated modal splits and the survey modal split, a new estimate is made of preference factor medians, and the associated modal-split error is determined. Using the latest two sets of preference factor

medians, this process continues until the modal-split error is within some preset limit (typically 0.5 percent of the modal split for each mode). When this limit is met for all modes, the preference-factor medians associated with the last simulation run are used directly for the 1980 modal-split runs under the assumption that qualitative traveler attitudes and preferences will not change significantly in the interim. The CTOL preference-factor distribution will be used for the STOL mode for the 1980 time period. The deviation parameter of the lognormal preference-factor distribution is determined for each mode, based on the estimated variation of traveler attitudes towards that mode prior to the calibration procedure. The purpose of the calibration procedure is to determine the distribution medians for each mode.

In order to obtain a unique set of preference medians for each calibration exercise, the median of the car preference-factor distribution is always set equal to 1.0. For n potential travel modes, this leaves n-1 unknown preference medians with which to fit n-1 known and independent fractional modal splits.

The results for the California Corridor are shown in Table C-7. The mode-preference factor medians for each city pair fell into three distinct groups depending on the intercity distance. San Francisco-Sacramento (70 miles apart) and Los Angeles-San Diego (110 miles) required significantly different preference-factor medians from those for other city pairs (340 to 450 miles). Therefore, one set of preference-factor distributions was used for all of the longer-stage-length city pairs, while each of the shorter-stage-length city pairs had its unique set. A single set of preference-factor medians was used for the four longer city pairs for two reasons. First, long city pairs which had San Diego as one of the cities had a weak survey modal-split data base, due to small samples and ambiguities between travelers originating in San Diego and those passing through from the south and east. Secondly, almost exact agreement was obtained between the two long city pairs having Los Angeles as one of the cities. Therefore, a single set of preference factors was used for all four long city pairs which, in all cases, produced an absolute error of less than 2 percent.

Table C-7. California Corridor Preference Factor Medians

Mode	"Long" City Pairs	Los Angeles-San Diego	San Francisco-Sacramento
CAR	1.0	1.0	1.0
CTOL	0.74	0.91	0.97
BUS	0.71	1.06	0.83
RAIL	0.67	0.76	No Service
"Long" city pairs are Los Angeles-San Francisco, Los Angeles-Sacramento, San Francisco-San Diego, and San Diego-Sacramento.			

Table C-8. Midwest Triangle Preference Factor Medians

Mode	Detroit-Chicago	Chicago-Cleveland	Detroit-Cleveland
CAR	1.0	1.0	1.0
CTOL	1.04	0.98	0.75
BUS	0.84	0.68	0.69
RAIL	0.65	0.60	No Service

Table C-9. Northeast Corridor Preference Factor Medians

Mode	New York Washington	New York Boston	Washington Boston	Washington Philadelphia	Washington Philadelphia
CAR	1.0/1.0	1.0/1.0	1.0/1.0	1.0/1.0	1.0/1.0
CTOL	1.09/1.03	1.20/1.15	0.97/1.22	0.85/0.83	1.10/1.18
BUS	1.00/1.06	0.97/1.10	0.71.1.00	0.76/0.87	0.86/1.06
RAIL	1.18/1.04	1.11.1.08	0.96/1.06	0.95/0.91	1.05/1.07
Business/Nonbusiness					

The preference-factor medians for the Midwest Triangle are shown in Table C-8. Unique preference factors were derived for each city pair, since a good data base existed. In both the California and Midwest arenas, only a single preference-factor median was derived for each mode, because the available data base did not differentiate between business and nonbusiness categories.

The preference factors for the Northeast Corridor are shown in Table C-9. In this case the data base generally divided the modal split on the basis of trip purpose, so separate preference-factor medians were derived for business and nonbusiness travelers for each mode for each city pair. A complete data base did not exist for Boston-Philadelphia, so the preference factors for this city pair were derived by taking a weighted (by city pair distance) average of the preference factors for Boston-New York and Boston-Washington and verifying that this set of factors gave reasonable results when applied to the 1980 no-STOL city pair data base.

A great deal of consistency in preference factors should not generally be expected from arena to arena, or even for different city pairs in the same arena. There are many factors unique to each city that the preference factors take into account. Several years ago in the early development of the model, various preference-factor biases were noted and eliminated by improving the fidelity of the quantitative modal-split model and expanding the data base feeding it. The fact that the preference factors are generally close to unity indicates that the nonquantitative aspects of modal choice do not drastically impact the basic, quantitative time/cost tradeoff by the traveler.

h. Zonal Characteristics

(1) Zonal Travel Demand

The concept of each zone having four types of demand (business/nonbusiness, resident/nonresident) was introduced earlier (Appendix B). Details of how resident population, income, work population, and hotel unit data are collected on a zonal basis will be described in a subsequent section.

The purpose of this section is to describe how this raw socioeconomic data on a zonal basis are converted to the four types of demand for each zone. The fundamental relationship between population and travel demand is the propensity to travel as a function of income. This relationship was derived from the 1967 Census of Transportation Data Tape using the steps outlined in Figure C-15. From this tape, travel propensity (person trips/household/year) was determined as a function of trip purpose (business or nonbusiness), trip distance interval, and region of the country for all trips originating within an SMSA for each household-income interval. The city pairs in each arena were grouped into distance intervals wide enough to include suburban origins and destinations, yet narrow enough to differentiate between close and distant city pairs. Income intervals were chosen consistent with the ten intervals on the data tape.

The propensity data taken from the tape were made continuous as a function of income by performing a least-squares error polynomial fit to the income interval data. This polynomial yielded travel propensity as a function of household income for a specified trip purpose and distance interval for each arena.

To obtain a propensity for an entire zone rather than an individual household, the lognormal distribution of income within that zone was taken into consideration. The propensity for a zone having median income m is

$$P_m = \int_i P(i) \cdot L_m(i)$$

where P(i) is the household propensity polynomial and $L_m(i)$ is the lognormal income density distribution for median zonal income m. While this procedure could have been performed repeatedly for each different zonal median income, the implementation was expedited by forming a zonal propensity polynomial from a set of such zonal median incomes. These zonal propensity polynomials were still unique to each arena, trip purpose, and distance interval. Four different zonal travel demands were used for each regional zone. The relative resident business demand and the relative resident nonbusiness demand were obtained by multiplying the zonal resident population by

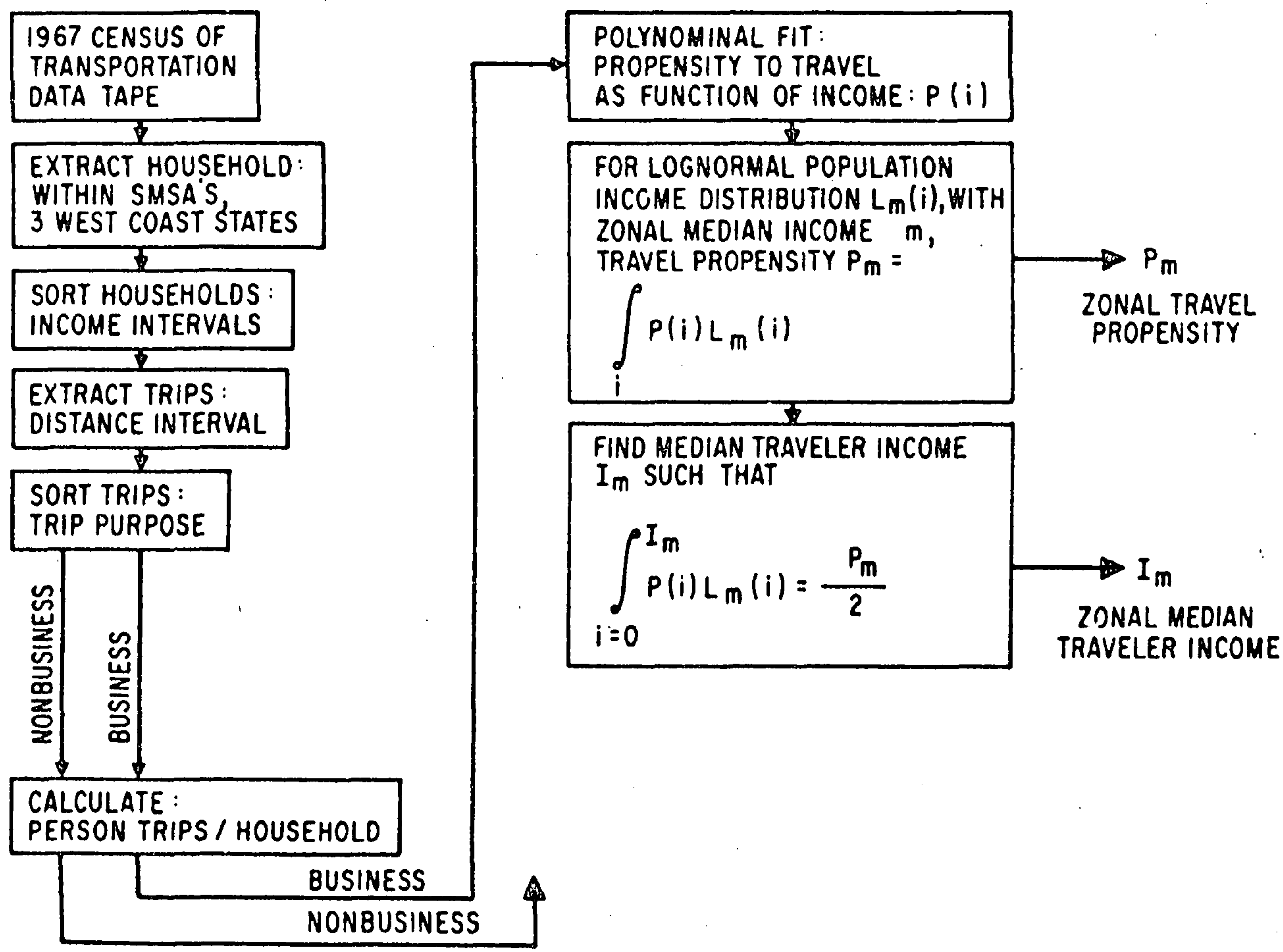


Figure C-15. Derivation of Zonal Travel Propensity and Traveler Income

the business travel propensity and nonbusiness travel propensity, respectively, associated with the resident income for that zone. The relative nonresident business demand was obtained by multiplying the zonal work-force population by business travel propensity associated with the income of the people working in that zone. (The conceptual implication is that businessmen travel to zones in proportion to that zone's workforce and that they have incomes similar to the people working in that zone.) Finally, the relative nonresident nonbusiness demand was obtained by augmenting the relative resident nonbusiness demand to account for the hotel/motel units in that zone. This adjustment was based on the ratio of nonbusiness visitors staying in a hotel to those staying in a residence, as determined from the Census of Transportation Data Tape.

(2) Contiguous City Travel Demand Adjustments

Nominally the distribution of a projected level of intercity travel demand between the zones comprising each region was determined by the relative values of the four propensities computed for each zone. However, when the intercity distance was small relative to the dimensions of the regions modeled, an adjustment to the nominal zonal-demand distribution was required. Failure to do so would have resulted in a predicted zonal demand that was too low for zones located virtually next to one another but in different regions, while an excess level of demand would be estimated for those zones whose intercity distances were maximum.

The distribution of zonal demand was assumed to be influenced by local variances in intercity distance only in the two city pairs whose regions were contiguous, namely, Los Angeles-San Diego and San Fransisco-Sacramento. To account for the distance effect, the propensities of the zones located within the larger regions (Los Angeles and San Francisco) were modified. Specifically, a multiplier was derived for each county within the Los Angeles and San Francisco regions and was applied to the nominal propensities of each zone within that county. Hence, the adjusted propensities maintained their relative distributions within each county, while the county-to-county

demand distributions were altered to reflect the effect of varying intercity trip distances. Total intercity demand was not affected.

The value assigned to each multiplier was defined by the ratio of the portion of total demand allocated to a given county obtained from auto origin and destination (O&D) survey statistics to that derived using the nominal zonal propensities aggregated to the county level. The distribution of auto travel demand between the Sacramento region and the counties of the San Francisco region was obtained from a Sacramento Area Transportation Study. In like manner, using data from the San Diego area cordon survey, the distribution of auto demand from the San Diego region to the counties of the Los Angeles region was determined.

(3) Traveler Income Distributions

The purpose of generating a traveler-income distribution instead of using a population-income distribution is to reflect the fact that travelers from a given zone have a higher median income than the general population of that zone. Determining the traveler median income for a zone (for a specified region and trip distance interval) whose overall population income is known is an extension of the technique used for determining travel propensity for a given zone (see Figure C-15). Fundamentally the procedure is to find, for a given zonal population-income median, that value of income, I_m such that half of the trips are taken from households having more than that income. Mathematically, the procedure is to find I_m such that

$$\int_{i=0}^{I_m} P(i) \cdot L_M(i) = \frac{P_m}{2}$$

Again, the implementation is expedited by forming a polynomial which gives the traveler-median income as a function of population-median income.

i. <u>Diurnal Distribution of Desired Departure Times</u>

The diurnal distribution of desired departure times arises from the fact that short haul air demand is not uniformly distributed throughout the

service day. Peaks exist in the morning and in the evening. The prime data source for diurnal demand is the Eastern Airline shuttle service, since it is the only substantial on-demand air service in the country.

However, this distribution is unique to the East Coast CTOL service day (note the very late P. M. demand shown in Figure 16). For this study, in all three arenas, the Eastern diurnal distribution was modified to reflect the shorter service day (nominally 14 hours) which exists in the California and Midwest arenas and which can be expected to exist in the 1980 time period in the Northeast Corridor for proposed STOL operations. Both the Eastern Airline shuttle demand and the modified diurnal-demand distribution used in this study are illustrated in Figure C-16. The modified demand distribution is in very good agreement with supporting, but limited, survey data from the United Airlines California shuttle service and data based on O'Hare operations and surveys.

j. Demand-Matching Routine

In addition to the STOL fractional modal split and maximum waiting time distributions for each STOL fare, the demand-matching routine uses the intercity total daily travel demand, a diurnal distribution of desired departure times, and a set of candidate schedules (departure headways).

This routine determines the average load factor (and actual number of passengers carried) for each combination of schedule, fare, and capacity factors using a Monte Carlo simulation. In this process each potential STOL traveler is assigned an explicit desired departure time and maximum waiting time. A traveler's desired departure time is sampled from a diurnal probability distribution representative of short haul air travel. His maximum waiting time is sampled from one of the waiting time distributions produced by the modal split routine. The actual distribution used depends on the traveler's desired departure time and service path. If the total time between a traveler's desired departure time and the time of the next unfilled flight is less than his maximum waiting time, he is assigned to that flight. If his waiting time is not large enough, or if there are no remaining available flights during the day, the traveler is considered lost to another mode.

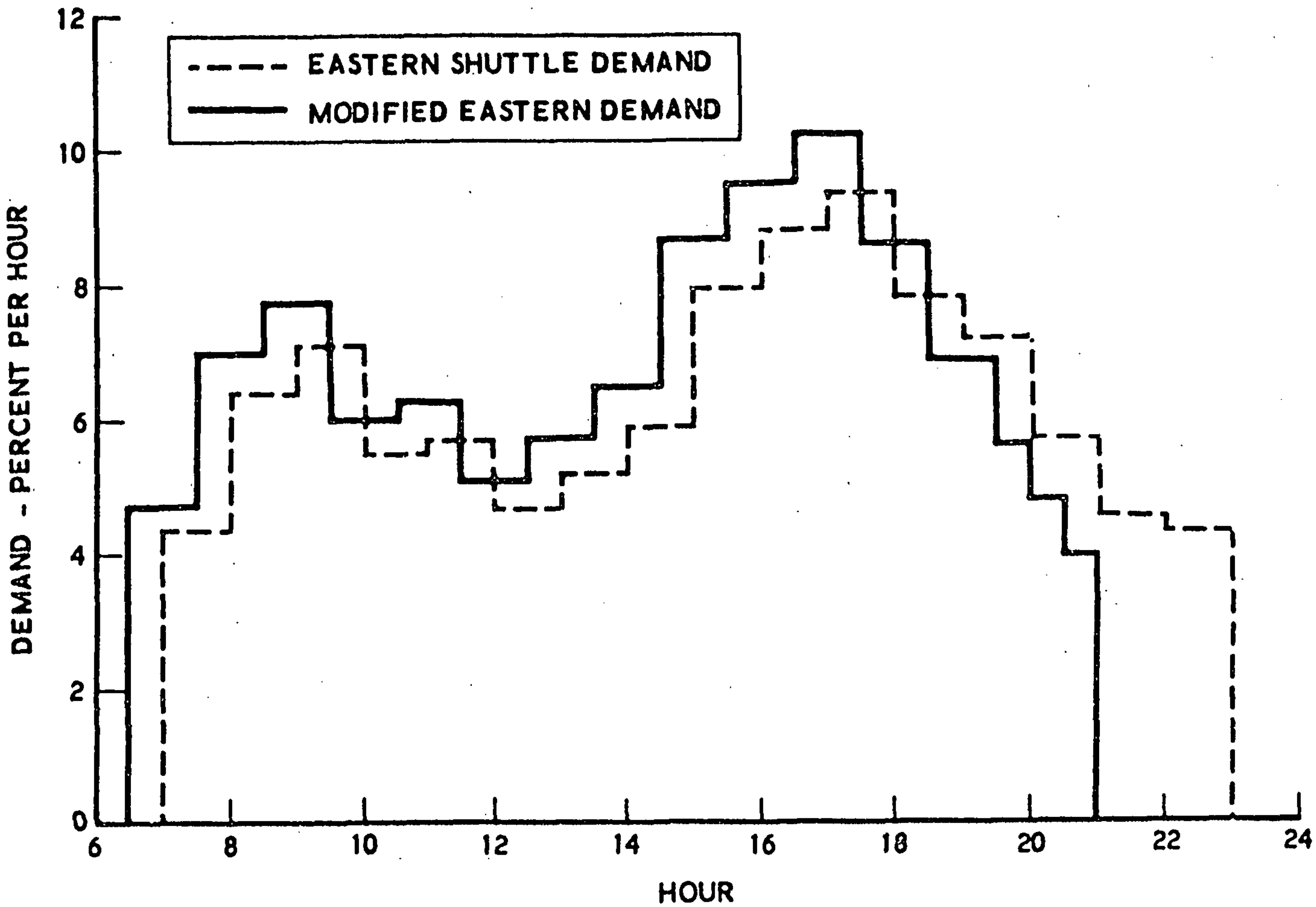


Figure C-16. Diurnal Distribution of Desired Departure Times

It is very cost-effective to separate the demand-matching from the modal-split routines. Many schedules and capacities for a specific fare can be tested for a minimal computer cost as opposed to rerunning the whole finite STOL frequency modal-split routine for each new STOL schedule. Typically, the demand-matching routine explicitly considers all possible combinations of 20 schedules, 20 fares, and 15 capacities for each service path of each service path set modeled. The disadvantage is that it is not possible to foretell to which modes the lost STOL travelers go. However, this can be determined after-the-fact for any schedule and fare of interest by rerunning the finite STOL frequency modal-split routine with the appropriate fare and STOL frequency of service (corresponding to the frequency of the given schedule).

Incorporated into the demand-matching program is a subroutine that identifies, for each of 20 fares, that frequency of service that will produce a stipulated average-load factor. In this study, that average-load factor was established at 65 percent. A minimum frequency of service constraint of four round trips per day per service path was employed in this study of high density STOL service. When the minimum frequency of service is reached, load factors less than 65 percent result with the obvious impact on economic viability.

VOLUME II

APPENDIX D

SUPPLEMENTARY RESULTS

CONTENTS

D. 1	STOLport Characterization	D-1
	a. Site Selection	D-1
	b. Alternate Site Evaluation	D-5
D. 2	STOL Service Characterization by City Pair	D-13
	a. Los Angeles-San Francisco	D-14
	b. Los Angeles-San Diego	D-18
	c. Other City Pairs	D-19
D. 3	STOL System Definition Sensitivities	D-46

FIGURES

D-1.	Los Angeles-San Francisco Transportation System, Intercity Characterization	D-16
D-2.	Los Angeles-San Francisco Transportation System, STOL System Sensitivities	D-17
D-3.	Los Angeles-San Diego Transportation System, Intercity Characterization	D-20
D-4.	Los Angeles-San Diego Transportation System, STOL System Sensitivities	D-21
D-5.	San Francisco-San Diego Transportation System, Intercity Characterization	D-22
D-6.	San Francisco-San Diego Transportation System, STOL System Sensitivities	D-23
D-7.	Sacramento-Los Angeles Transportation System, Intercity Characterization	D-24
D-8.	Sacramento-Los Angeles Transportation System, STOL System Sensitivities	D-25
D-9.	San Francisco-Sacramento Transportation System, Intercity Characterization	D-26

FIGURES (Continued)

D-10. San Francisco-Sacramento Transportation System, STOL System Sensitivities D-27

D-11. Sacramento-San Diego Transportation System, Intercity Characterization D-28

D-12. Sacramento-San Diego Transportation System, STOL System Sensitivities D-29

D-13. Chicago-Detroit Transportation System, Intercity Characterization D-30

D-14. Chicago-Detroit Transportation System, STOL System Sensitivities D-31

D-15. Chicago-Cleveland Transportation System, Intercity Characterization D-32

D-16. Chicago-Cleveland Transportation System, STOL System Sensitivities D-33

D-17. Detroit-Cleveland Transportation System, Intercity Characterization D-34

D-18. Detroit-Cleveland Transportation System, STOL System Sensitivities D-35

D-19. New York-Washington, D. C. Transportation System, Intercity Characterization D-36

D-20. New York-Washington, D. C. Transportation System, STOL System Sensitivities D-37

D-21. New York-Boston Transportation System, Intercity Characterization D-38

D-22. New York-Boston Transportation System, STOL System Sensitivities D-39

D-23. Boston-Washington, D. C. Transportation System, Intercity Characterization D-40

D-24. Boston-Washington, D. C. Transportation System, STOL System Sensitivities D-41

FIGURES (Continued)

D-25. Boston-Philadelphia Transportation System, Intercity Characterization D-42

D-26. Boston-Philadelphia Transportation System, STOL System Sensitivities D-43

D-27. Philadelphia-Washington, D.C. Transportation System, Intercity Characterization D-44

D-28. Philadelphia-Washington, D.C. Transportation System, STOL System Sensitivities D-45

TABLES

D-1. Northeast Corridor STOLport Site Selection Process Sites . D-2

D-2. Midwest Triangle STOLport Site Selection Process Sites D-3

D-3. Example of California Corridor STOLport Selection Process, Los Angeles Region D-4

D-4. California Corridor STOL System Service Paths D-6

D-5. Representative STOL System Characteristics, California Corridor, 150-Passenger Aircraft, ROI = 8% D-47

D-6. Representative STOL System Characteristics, California Corridor, 50-Passenger Aircraft, ROI = 8% D-48

D-7. Representative STOL System Characteristics, California Corridor, 100-Passenger Aircraft, ROI = 8% D-49

D-8. Representative STOL System Characteristics, California Corridor, 200-Passenger Aircraft, ROI = 8% D-50

D-9. Representative STOL System Characteristics, California Corridor, 150-Passenger Aircraft, ROI = 0% D-51

TABLES (Continued)

D-10. Representative STOL System Characteristics, California Corridor, 150-Passenger Aircraft, ROI = 5.25% D-52

D-11. Representative STOL System Characteristics, California Corridor, 150-Passenger Aircraft, ROI = 12.5% D-53

D-12. Representative STOL System Characteristics, Midwest Triangle, 150-Passenger Aircraft, ROI = 8% D-54

D-13. Representative STOL System Characteristics, Midwest Triangle, 50-Passenger Aircraft, ROI = 8% D-55

D-14. Representative STOL System Characteristics, Midwest Triangle, 100-Passenger Aircraft, ROI = 8% D-56

D-15. Representative STOL System Characteristics, Midwest Triangle, 200-Passenger Aircraft, ROI = 8% D-57

D-16. Representative STOL System Characteristics, Midwest Triangle, 150-Passenger Aircraft, ROI = 0% D-58

D-17. Representative STOL System Characteristics, Midwest Triangle, 150-Passenger Aircraft, ROI = 5.25% D-59

D-18. Representative STOL System Characteristics, Midwest Triangle, 150-Passenger Aircraft, ROI = 12% D-60

D-19. Representative STOL System Characteristics, Northeast Corridor, 150-Passenger Aircraft, ROI = 8% D-61

D-20. Representative STOL System Characteristics, Northeast Corridor, 50-Passenger Aircraft, ROI = 8% D-62

D-21. Representative STOL System Characteristics, Northeast Corridor, 100-Passenger Aircraft, ROI = 8% D-63

D-22. Representative STOL System Characteristics, Northeast Corridor, 200-Passenger Aircraft, ROI = 8% D-64

D-23. Representative STOL System Characteristics, Northeast Corridor, 150-Passenger Aircraft, ROI = 0% D-65

TABLES (Continued)

D-24. Representative STOL System Characteristics, Northeast Corridor, 150-Passenger Aircraft, ROI = 5.25% D-66

D-25. Representative STOL System Characteristics, Northeast Corridor, 150-Passenger Aircraft, ROI = 12% D-67

APPENDIX D

SUPPLEMENTARY RESULTS

The material presented in this appendix either supports or supplements the results presented in Volume I (Ref. 39). The supporting data consist of a description of the STOLport siting process and parametric demand, fare, and service path sensitivities with respect to vehicle size and ROI on an individual city pair basis. Optimum STOL system characteristics for vehicle size/ROI combinations differing from the single 150-passenger, 8-percent set described in Volume I encompass the supplementary results presented herein.

D. 1 STOLPORT CHARACTERIZATION

a. Site Selection

The transportation system simulation (TSS) program was utilized to determine preferred STOLport locations, using existing airfields when practical. Two approaches were used, depending on the number of candidate sites available. When only a limited number of potential STOLport sites were available, such as in the Northeast Corridor or in the Midwest Triangle, all possible combinations of ports in both cities were modeled in a modal split run. The service path attracting the greatest demand was designated as the first service path between the two cities. Combining the first path (and its ports) with all possible second paths identified the two-path set which produced the greatest STOL demand between the two cities. The process was repeated to determine the best set of 3, 4, 5, and (for some city pairs) 6 service paths. Tables D-1 and D-2 identify the candidate site locations examined in the Northeast Corridor and the Midwest Triangle, respectively, together with the selected service path combinations.

The California Corridor, with more than 50 potential sites in the Los Angeles region alone, required a different technique. Service paths were modeled between each potential site in one city to a single common

Table D-1. Northeast Corridor STOLport Selection Process Sites

Candidate STOLport Locations

New York	Philadelphia	Boston	Washington
Floyd Bennett Flushing Islip Mitchel Republic Secaucus* Teterboro Westchester Co.	North Phil.	Bedford Beverly Logan Int. Norwood	CBD* College Pk. Montgomery Prince George s Airpark
*New Port			

Selected Service Paths

City Pair	New York Washington		New York Boston		Boston Washington	
Service Path Order						
1	Sec	Coll Pk	Sec	Logan(1)	Coll Pk	Logan(1)
2	Mitch	Coll Pk	Mitch	Logan	Coll Pk	Bedford
3	West	Coll Pk	West	Logan	Pr Geo	Logan
4	Sec	Pr Geo	Sec	Bedford	Pr Geo	Bedford
5	Mitch	Pr Geo	Mitch	Bedford		
6	West	Pr Geo	West	Bedford		

City Pair	Philadelphia Boston		Philadelphia Washington	
Service Path Order				
1	N. Phil	Logan(1)	N. Phil	Coll Pk
2	N. Phil	Bedford	N. Phil	Pr Geo

(1) Logan was ranked first at the request of local planning agencies. Bedford was slightly more attractive based on demand.

Table D-2. Midwest Triangle STOLport Selection Process Sites

Candidate STOLport Locations

Chicago	Detroit	Cleveland
Evanston* Howell Midway Meigs Mitchel Pal-Waukee	Berz CBD* Detroit City Mettetal	Bosworth Burke Lakefront Cuyahoga Co.
*New Port		

Selected Service Paths

City Pair	Chicago Detroit		Chicago Cleveland		Detroit Cleveland	
Service Path Order						
1	Meigs	D. City	Meigs	Burke	D. City	Burke
2	Meigs	Mett	Mitch	Burke		
3	Mitch	D. City	Meigs	Bos-worth		
4	Meigs	Berz				

point in another city. Modal split simulations were made assuming uniform STOL frequency of service (45-minute departures and $16.00 fares between Los Angeles and San Francisco). All possible service paths from the ports postulated in the Los Angeles region to a single port, Crissy Field, in the San Francisco region were investigated. Thus, the differences in demand between the Los Angeles ports were due solely to their locations relative to one another. The ranking of the relative levels of demand attracted to each of the 31 ports, as defined by modal split simulation, is listed under the second cull of Table D-3.

Based primarily on this ranking, port locations attracting the fewest travelers were eliminated, and the process was repeated. Over 20 different

Table D-3. Example of California Corridor STOLport Selection Process, Los Angeles Region

Candidate STOLports After First Cull	2nd Cull		3rd Cull		4th, 5th, 6th and 7th Cull		8th Cull		Final Rank
	Rank	Action	Rank	Action	Rank	Action	Rank	Action	
Chaves Ravine	2	Retained	2	Retained	1a	Retained	4	Retained	2
Fullerton Municipal	1		1				1		1
Morrow	21		4				3		3
Van Nuys	5		5		1c		2	Retained	4
El Monte	3		3		1b		5	Excluded	
Hawthorne Municipal	12		7		1d		6		
Orange County	8		15				7		
Santa Monica Municipal	6		8			Retained	8	Excluded	
Brackett Field	9		11		2b	Excluded			
Compton	4		6		2d				
Patton	Omitted		Omitted		2a				
Santa Susana	11		13		3c				
Torrance Municipal	13		10		3d				
Whiteman	17		14	Retained	2c	Excluded			
Burbank	7		19	Excluded					
Capistrano	15		16						
Long Beach	10		18						
Los Angeles International	18		21						
Meadowlark	14		12						
Ontario International	24		20						
Riverside	16		9						
Ventura County	19	Retained	17	Excluded					
Banning	29	Excluded							
Big Bear City	30								
Corona	22								
Hemet Ryan	28								
Palmdale	20								
Perris Valley	27								
Redlands	25								
Santa Paula	26								
Tri City	23	Excluded							

combinations of Los Angeles region ports tested using the modal-split program The results of the decisive tests are presented in Table D-3, which identified Chavez Ravine, Fullerton Municipal, Morrow, and Van Nuys as the preferred set of four ports.

This process was repeated for the other three regions within the California Corridor, identifying Lindbergh Field and Sacramento Executive as the best single-port locations in the San Diego and Sacramento regions, respectively, and Crissy Field, Palo Alto, Concord, and Marin as the best four locations within the San Francisco region.

During the course of the study, four of these port locations were changed:

- Morrow was replaced by Tri-City (based on a regional FAA recommendation).
- Montgomery was substituted for Lindbergh Field because of possible congestion at Lindbergh by the 1980 time period.
- Crissy Field was replaced by India Basin because of potential unavailability of Crissy Field.
- Chavez Ravine was replaced by Patton Military Reservation because of the high costs and local opposition anticipated in converting the Chavez Ravine to a level area.

The final set of service paths used in the parametric California Corridor analysis is listed in Table D-4.

b. Alternate Site Evaluation

The procedure used to establish the preferred alternate sites to serve the San Francisco and Los Angeles central business district (CBD) demand centers, replacing Crissy Field and Chavez Ravine, is described in the following paragraphs.

(1) San Francisco Alternate Site Considerations

The sites considered for San Francisco included locations identified and designated as primary by Multidisciplinary Associates (MDA) (Ref. 1) and are as follows:

Table D-4. California Corridor STOL System Service Paths

City Pair	Service Path	Candidate Service Path Sets 1	2	3	4	5
Los Angeles San Francisco	Patton — India Basin	●	●	●	●	●
	Patton — Palo Alto		●	●	●	●
	Fullerton — India Basin		●	●	●	●
	Patton — Concord			●	●	●
	Tri City — India Basin			●	●	●
	Fullerton — Palo Alto			●	●	●
	Van Nuys — India Basin				●	●
	Van Nuys — Palo Alto				●	●
	El Monte — India Basin					●
	El Monte — Palo Alto					●
Total Number of Service Paths in Each Set		1	3	6	8	10
San Francisco San Diego	India Basin — Montgomery	●	●	●		
	Palo Alto — Montgomery		●	●		
	Concord — Montgomery			●		
Total Number of Service Paths in Each Set		1	2	3		
Los Angeles Sacramento	Patton — Sacramento Executive	●				
Total Number of Service Paths in Each Set		1				
Los Angeles San Diego	Patton — Montgomery	●				
Total Number of Service Paths in Each Set		1				
San Diego Sacramento	Montgomery — Sacramento Executive	●				
Total Number of Service Paths in Each Set		1				
San Francisco Sacramento	India Basin — Sacramento Executive	●				
Total Number of Service Paths in Each Set		1				

- Central Bay Terminal
- Treasure Island
- Crissy Field
- China Basin
- Mission Rock
- India Basin
- West Oakland

After a field inspection and evaluation trip, all but Crissy Field and India Basin were deemed to be unacceptable, and an additional siting effort was initiated. This effort resulted in identification of the following potential sites:

- Hunter's Point
- Bay Shore/Brisbane Fill Area
- San Bruno Mountain Site
- Old Fort Funston

The final decision for an alternate site was made in favor of India Basin. Factors leading to this decision are discussed in the following paragraphs. It should be noted, however, that the evaluation and selection process was of a limited scope and was established with the primary goal of satisfying the objectives of this study.

Central Bay Terminal. A floating terminal was proposed in the Central Bay Region. Waterborne systems have previously been compared to land installations on a capital cost and 10-year operating cost basis for other types of systems. Invariably, they have shown severe cost penalties in both categories. Transportation time from the CDB is excessively high. A 20 to 40 minute water ferry ride from the Ferry Building or the Oakland Water Terminal was estimated in earlier studies (Ref. 43). Transit time from the CBD to the waterfront and transport-mode transfer time when added to the ferry time heavily penalizes this concept in terms of modal-split criteria. These factors eliminated this site from additional consideration.

Treasure Island. A STOLport located 1,000 feet north of the island on a pier structure was postulated for this site. The construction of this concept requires deep pile foundations driven into the bay mud to support the structure. Columns at least 55-feet high are required between the pilings and the base of the airport structure. This height is required to clear high tides and severe wave action. This is a complex structure and would involve excessive construction costs. The parking terminal and support facilities, which would be best located on the island itself, involve access to the landing strip by a 1,000-foot causeway. Transportation to the site is stated to be via the Oakland/San Francisco Bay Bridge or a water transport link. Unless special provisions can be made with the Navy, private vehicular traffic would not be allowed on the Naval Base, forcing prospective STOL passengers to utilize either bus or water transportation from the mainland in San Francisco or Oakland. These factors eliminated the site from further consideration.

Crissy Field. Crissy Field is an existing Army airfield having a runway of sufficient length to support the STOL operations. Additions and modifications to convert the field to commercial STOL usage are minimal. From technical considerations, this site was the location preferred of all those considered.

China Basin. Directly west of the China Basin wharf area is an area owned by the Southern Pacific Railroad, which is used as a railroad yard and for industrial warehousing. Joint use of the area with railroad and warehousing activities continuing unabated was postulated in Ref. 43. An overhead structure is proposed to facilitate multiple use. The depth to bedrock is approximately 150 feet, with the shallow beds consisting of bay mud and hydraulic fill (Ref.43). Deep piles probably extending to the bedrock would be required for the foundation. The overhead structure would be interconnected with the foundation by columns probably 50 to 60 feet in height. In essence, the structure would resemble a bridge or freeway overpass-type of structure. However, its design would be more complex inasmuch as this

structure, unlike others, would have to consider heavy live loads in its design. Construction costs would be excessive for this concept.

The railroad and warehousing facilities support the contiguous shipping area, which is important to the commercial life of San Francisco. It is inconceivable that these facilities could be shut down or that their operations could be hampered to any significant degree during construction. Yet, extensive shutdowns would be required for safety reasons during the overhead construction. For these reasons, this site was eliminated from additional consideration.

Mission Rock. Mission Rock is a long wharf that extends into the bay adjacent to China Basin. It includes the waterfront and cargo facilities for Piers 48 through 56. Multiple use was again postulated in Ref. 43. A North-South runway spanning the end of the pier as an overhead structure, with the ocean shipping activities continuing without impediment, was envisioned. The pier facility must be able to handle C-5 transport ships as a minimum, plus any prospective new class of cargo ships now in the planning stage. The C-5 transport has, in some versions, superstructures and handling equipment that extend 120 feet above the water line. This would mean the elevated structure would have to provide at least 130 feet of clearance above the high water mark. The comments made relative to the complex structure in China Basin also apply to this plan. This waterfront facility would also be shut down for extended periods of time during the construction phase. It is believed to be an unacceptable condition, and these factors removed the site from further consideration.

India Basin. The India Basin site is a hydraulic fill area, due south of India Basin itself. There is sufficient land area to support all of the requirements of the STOLport configurations under consideration. Current land usage is minimal. From a construction point of view, all construction would take place on the land surface; i.e., there is no requirement for elevated structures. The fill and subsurface material has poor structural characteristics, and piling-type foundations will also be required at this

site. The depth to bedrock is estimated to be 150 to 200 feet, and full-depth pilings may be required. In this case, the structural approach would be to span piling clusters with grade beams and to construct the runways and other surface facilities upon these. Access to the site is via Third Street, which is a major thoroughfare to the CBD. A short stretch of Evans Avenue on the STOL site itself would have to be improved to provide adequate vehicular circulation characteristics.

The overall evaluation of this site established that it was a viable candidate from an engineering and construction standpoint.

West Oakland. This proposed site is owned by the Southern Pacific Railroad and consists of a railroad switching yard located in West Oakland at the foot of Peralta Street. Multiple use of the site was proposed (Ref 43) with the STOLport constructed as an overhead structure while the railroad switching yard continues its normal operation. This switching yard supports a large portion of the Oakland Water Terminal cargo-handling facilities as well as the U. S. Navy Supply Depot and Alameda Air Station, and its continued use appears to be of importance to the economy of the Oakland community.

The subgrade material is bay mud and fill with a depth to bedrock estimated at 300 feet. The same type of design and construction process as discussed for China Basin applies to this site, with the exception that the piling foundations would probably be deeper and/or more extensive. As with China Basin, it is difficult to envisage a feasible construction process that would not shut railway activities down for a long duration of construction stages. This site was not given further consideration as an alternative STOLport for these reasons.

Hunter's Point. This site is located on the north shore of Hunter's Point and is immediately adjacent to the west border of the Naval Station located thereon. It is a fill location on the shore of the bay and is approximately 2,000 feet long by 1,000 feet wide. In order to obtain sufficient area for a 2,000-foot runway, however, approximately 500 feet of estuary would have to be filled in.

Depth to bedrock is unknown here, but it is believed to be relatively shallow because of its close proximity to hardrock outcrops southwest of the site. The dip and strike of these outcrops indicate that the depth of bay mud is probably less than 100 feet. Surface-type structures would be utilized here with short pile and grade beam foundations.

Access to the site is from Third Street via Evans Avenue and Hunter's Point Boulevard. Evans Avenue and Hunter's Point Boulevard would require improvements for satisfactory vehicular circulation. It is estimated that the cost of construction would be equivalent to, or more than, the China Basin site and would involve a greater amount of travel from the CBD than would India Basin.

Bay Shore/Brisbane Fill Area. This site is located east of the San Bruno Mountains and is an island formed by the James Lick Freeway (101) and the Bay Shore Highway. The proposed site would be located south of the Champion Speedway, contiguous to Visitacion Point. Operation of the STOL-port would not interfere with any of the adjacent land uses. The depth to bed-rock is believed to be shallow because the site itself is located at the foot of the San Bruno Mountains, which are igneous in nature. The dip and strike of the nearby rock outcrops indicate a depth of fill and mud of less than 100 feet, possibly less than 50 feet. Therefore, structures using piling and grade-beam foundations would represent a low cost project when compared with any of the other candidates. Because of the proximity to both the Bay Shore Highway and the freeway, access is good although an additional on-off ramp may be required. From a civil engineering standpoint, the site is believed to be equivalent to India Basin. This site would involve a greater amount of travel from the CBD than would India Basin and, as a result, was eliminated from further consideration.

San Bruno Mountain Site. This site would be located on the crest of one of the prominent mountain ridges on San Bruno Mountain, probably on the eastern side for the freeway proximity. Site preparation would include level-ing a 2,000 by 500-foot area of hard igneous rock, and the cost would be ex-cessive.

Access roads would have to be constructed between the freeway and the STOLport across an elevation change of approximately 800 feet in less than 1/2 mile. Road costs would be excessive. The environmentalists' position relative to the use of San Bruno Mountain as a STOLport is an unknown factor at this time. Inasmuch as it is one of the few remaining primitive areas in the San Francisco region, an adverse reaction seems highly probable. This site was eliminated from additional consideration for the above factors.

Old Fort Funston. The Old Fort Funston area is located adjacent to Harding Park and Lake Merced. It is a narrow strip of ground lying between the Park and the Pacific Ocean. One-half of the Fort has been deeded to San Francisco by the Federal government and has been designated a park area. The remainder of the reservation is used as a Nike site. The Nike site has insufficient area for a STOLport, and additional land would have to be reacquired from the San Francisco Parks Department. Contact with that department indicated a very low likelihood of changing the use of their land. By local law, any area designated for park or recreation use can have its use changed only through a vote of the electorate. The probabilities of this occurring are considered to be nil. This site was dismissed from additional consideration.

Based on these evaluations, India Basin appeared to be the preferred alternative to Crissy Field, and it was therefore selected in this study as the site to serve the San Francisco CBD.

(2) Los Angeles Alternate Site Evaluations

Chavez Ravine was eliminated as a viable STOLport location because of anticipated rejection by the citizenry of the required land use change. A map study was initiated and alternate sites were proposed for further consideration. They were:

- Los Angeles River Flood Control Channel
- General George S. Patton Military Reservation

Los Angeles River. One section of the Los Angeles River Flood Control Channel lying in an east/west direction appeared attractive during the map study stages. The engineering approach for using this concrete-lined flood control channel would be to bridge it with the runway structure over a length of 2,000 feet. The terminal, parking, and support facilities would be located on a site acquired immediately adjacent to the channel. The candidate site is located in the city of Vernon, immediately north of East Vernon Avenue. This is the only section of the river that runs parallel with the prevailing wind for a sufficient distance for satisfactory runway lengths. The site itself is aesthetically unpleasant. It is in the middle of the slaughter house district of Los Angeles, and the effluent discharge to the river in the area could be offensive. Construction costs of the bridge-type structure would be high and, if growth were to be required in either total area or length of runway, the site would be unacceptable.

Patton Military Reservation. The remaining alternate site was the George S. Patton Military Reservation located in the City of Commerce near the junction of the Santa Ana and Long Beach Freeways. Its distance from the CBD is about equivalent to that of Chavez Ravine. A portion of the base is being used as a Federal center and by the Post Office Department for trans-shipment purposes. The subsurface soil condition appears to be adequate for supporting a STOL runway and its adjacent facilities, so a minimum of site preparation expense is anticipated. The land use of the adjacent area is all heavy manufacturing, so that minimal impact would be expected on the surrounding community activities. This site was, therefore, selected in place of Chavez Ravine.

D.2 STOL SERVICE CHARACTERIZATION BY CITY PAIR

STOL system activities with respect to vehicle size and ROI, presented in Volume I, Section VI-A (Ref. 39), were derived by aggregating individual city pair results to an arena level. To facilitate an examination of STOL service potential at the city pair level, additional parametric data are presented in this section for each of the 14 city pairs included in this study.

For each city pair a summary of the characteristics of the non-STOL modes, projected 1980 travel demand, and intercity distances are reiterated to describe the setting in which STOL service potential was examined. Intermediate results predicting STOL potential demand sensitivity to fare and number of service paths is then established without consideration of the economic consequences; i.e., ROI. It is "potential" demand, because it does not take into account travelers' waiting time caused by either infrequent service or insufficient vehicle capacity. Finally, actual demand, accounting for travelers' waiting time and STOL system economics, is presented for variations in vehicle size and ROI. These results are illustrated together with the resulting one-way fares and optimum number of service paths. Vehicle capacities that cannot achieve the stipulated ROIs are excluded from these data. Thus the remaining range of vehicle capacities and ROIs illustrated on each of the resulting plots provide one measure of STOL service potential between the designated cities.

The 28 figures in this appendix present all of the previously mentioned information for each of the 14 city pairs. The process of drawing conclusions with respect to STOL service potential is exemplified in the following discussion of the Los Angeles - San Francisco and Los Angeles - San Diego city pairs.

a. Los Angeles - San Francisco

The domination of the Los Angeles - San Francisco city pair in the California Corridor air transportation market is evidenced by a projected 1980 CTOL demand (without STOL competition) that is almost twice that of the combined total of the other five California Corridor city pairs. A total intercity O & D demand (all modes) averaging 37,780 daily person-trips between the Los Angeles and San Francisco regions (a distance of approximately 355 air miles) is projected for 1980. STOL service competition consists of three common carriers and the private car, whose port locations are identified and characteristics summarized in Figure D-1.

In all cases, the car times and costs defined in the tables of the odd-numbered figures were not based on city-center to city-center distances but instead reflect intercity distances measured from fictitious car ports, which

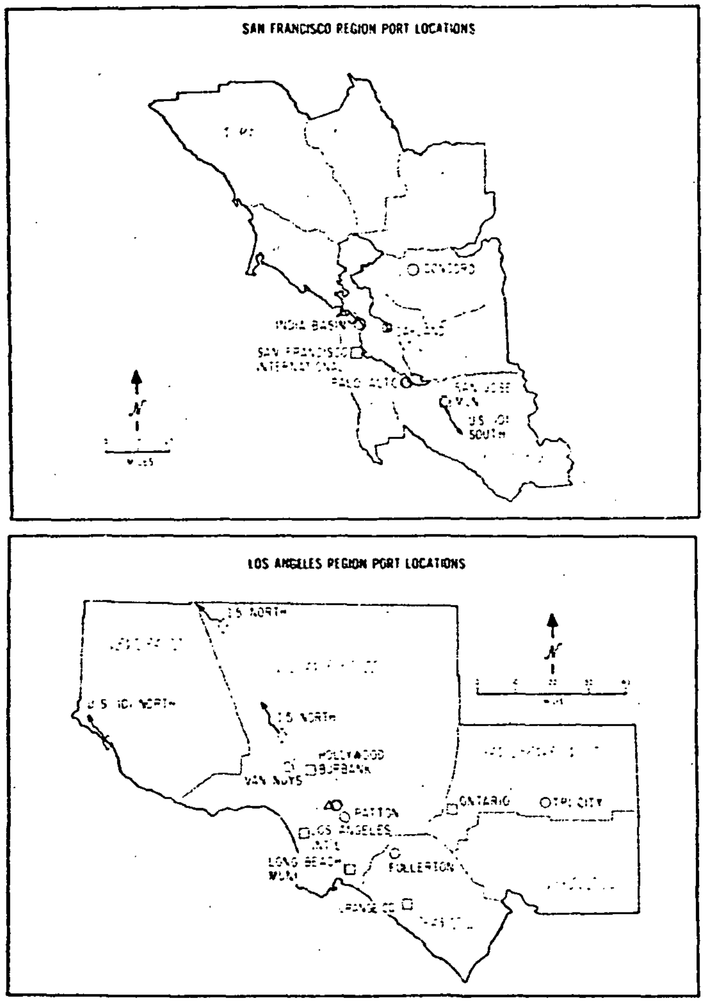
were generally located at the intersection of the regional boundaries and the main highways between the regions. Transportation from the traveler's O&D location to the modal ports is taken into account through the use of a local travel function, but it is not incorporated into the data presented in the aforementioned figures.

The attractiveness of STOL service from the traveler's point of view, considering fares and route structures, can be estimated from the data presented in the potential demand curves of Figure D-2. An examination of these curves leads to the following conclusions:

- STOL modal split decreases at about 4 percent for every one dollar (5 to 10 percent) in fare increase.
- At the CTOL fare ($16.50) STOL could attract from 45 to 90 percent of the "No STOL" CTOL patronage, depending on the number of service paths. It should be noted that the STOL system, being a new mode of transportation, attracts travelers from and at the expense of all competing modes: CTOL, auto, rail and bus, though primarily from the most similar mode; namely, CTOL.
- One-half of the "No STOL" CTOL demand level could be attracted to STOL service if the fares were kept below $20 for the 8-path case, or below $16 for the single-service path

STOL viability cannot be assessed until the relationship between STOL patronage and ROI is determined. This analysis, which considers not only the fares and number of service paths but also the impact of schedules and vehicle capacity, is conducted in the modal split and economic analysis portions of the Transportation System Simulation (TSS) program (Appendix C). Application of the TSS produced a data base that was used to construct the vehicle size/ROI sensitivity plot of Figure D-2. That plot illustrates the variation in demand, one-way fare, and optimum number of service paths for each combination of vehicle size and ROI examined.

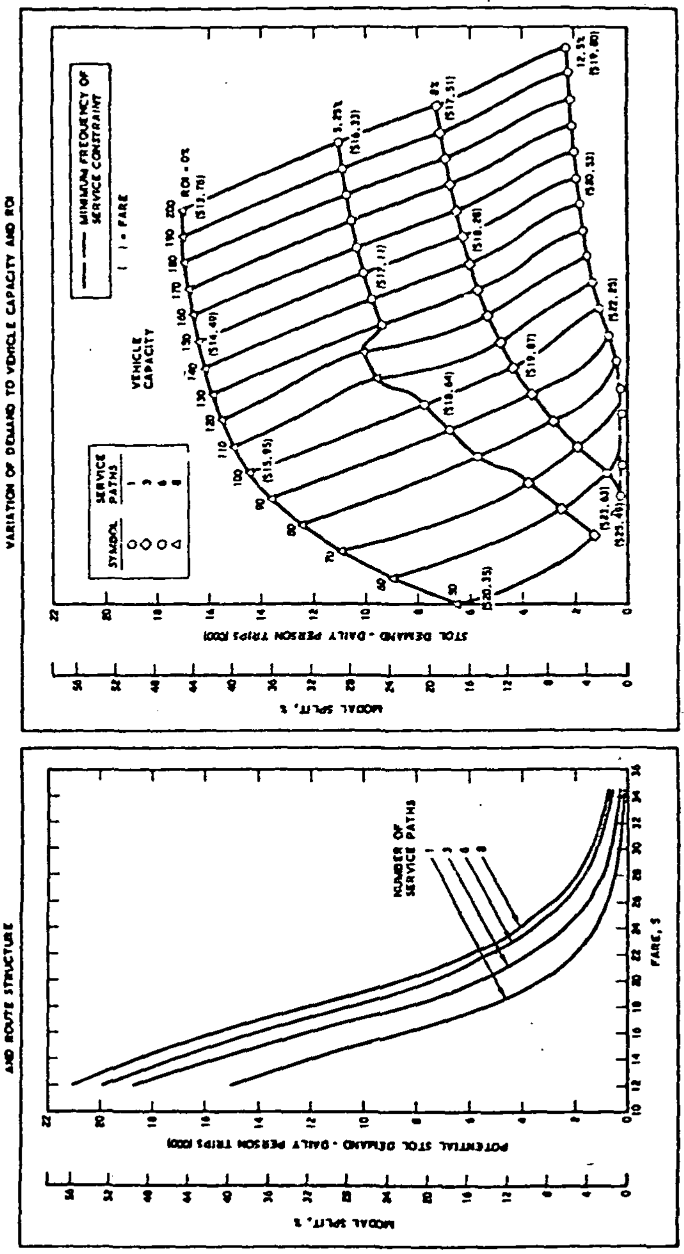
The rapid increase in demand on the ROI = 5.25 percent contour for vehicle sizes of 110 and 120 passengers is due to the use of an 8-service-path set, which failed to produce a 5.25 percent ROI with vehicle capacities ranging between 50 and 90, or 130 and 200 passengers. Demand is quite sensitive to



○ STOL
□ CTOL
◇ CAR
△ BUS
○ RAIL
CBD

1980 TOTAL INTERCITY O & D DEMAND 37,780 DAILY PERSON TRIPS					
NOMINAL INTERCITY DISTANCE - 355 AIR MILES					
MODE	REPRESENTATIVE MODE CHARACTERISTICS				
	TIME (hrs)	COST ($)	FREQ. (dep. per hour)	No. OF PORT PAIRS SIMULATED	MODAL SPLIT W/O STOL
CAR	6.26	13.80	-	3	54 %
CTOL	1.00	16.50	2.43	13	43
BUS	9.00	13.50	1.35	1	2
RAIL	10.67	16.00	0.07	1	1

Figure D-1. Los Angeles-San Francisco Transportation System Intercity Characterization



STOL SERVICE PATH SET DEFINITION

SERVICE PATH PORT LOCATIONS	NUMBER OF SERVICE PATHS IN STOL ROUTE STRUCTURES: 1	3	4	8
PATTON-INDIA BASIN	○	◇	○	△
PATTON-PALO ALTO		◇	○	△
FULLERTON-INDIA BASIN		◇	○	△
PATTON-CONCORD			○	△
TRI CITY-INDIA BASIN			○	△
FULLERTON-PALO ALTO				△
VAN NUYS-INDIA BASIN				△
VAN NUYS-PALO ALTO				△

Figure D-2. Los Angeles-San Francisco Transportation System STOL System Sensitivities

Figure D-2. Los Angeles-San Francisco Transportation System STOL System Sensitivities

ROI, dropping from roughly 15,000 daily person-trips (representing 40 percent of all travel between the Los Angeles and San Francisco regions) at zero ROI, to virtually no demand at an ROI of 12.5 percent. At a more reasonable ROI of 8 percent, some 7,000 daily person-trips are anticipated over three STOL service paths (Patton-India Basin, Fullerton-India Basin, and Patton-Palo Alto). For equal demand levels, the lower fares identified on the vehicle capacity-ROI sensitivity plot, relative to those of the potential demand curve, compensate in the traveler's modal choice process for the impact of schedules and capacity limitations, i.e., waiting times which are not taken into account in the derivation of the potential demand-fare curves. Vehicle capacities between 100 and 200 passengers look promising, with an increasingly sharp drop in patronage when smaller vehicles with higher per-seat operating costs (and consequent higher fares) are utilized. All vehicle capacities examined could produce an 8-percent ROI, with only the smaller vehicle sizes not achieving either a 10.5 or a 12.5-percent ROI. It is interesting to contrast this almost complete region of economic viability with the virtually nonviable example of Los Angeles-San Diego.

b. Los Angeles - San Diego

Los Angeles and San Diego, whose city centers are about 100 miles apart, will produce an estimated 76,470 daily person-trips in 1980. CTOL without competitive STOL attracts only 4 percent of the O&D travelers, while auto would capture 88 percent of the demand. The port locations and system characteristics of the alternative modes are shown in Figure D-3.

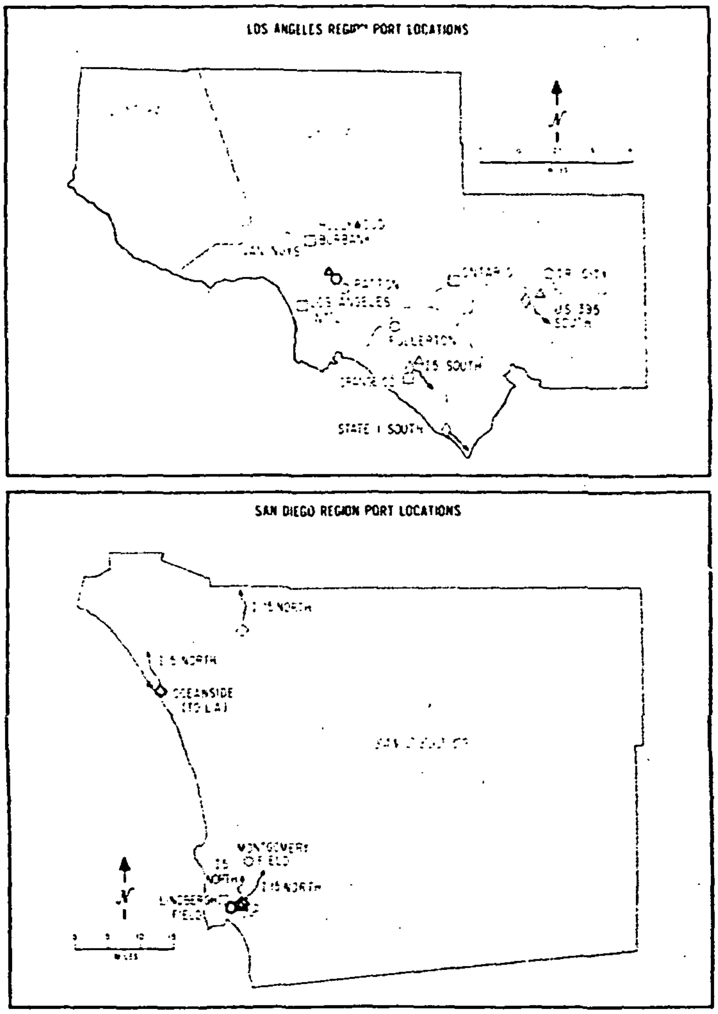
As shown by the potential demand curve of Figure D-4, STOL demand would exceed that of "No STOL" CTOL at the same fare ($8.29). However, application of that fare to STOL service resulted in a negative ROI. Increasing fares rapidly reduced patronage below that level required to support the minimum of four round trips per day, resulting in only a small range of attainable ROIs between 0 and 3 percent, and excluding vehicle capacities of 50, 60, and 200 passengers as shown in the vehicle capacity/ROI sensitivity plot of Figure D-4.

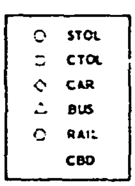
This marginal performance by the STOL system can be attributed to the short intercity distance between the Los Angeles and San Diego regions (which, as modeled, were actually contiguous) resulting in a relative door-to-door, trip-time advantage for automobile travel.

c. Other City Pairs

Similar data for each of the 12 remaining city pairs are presented in Figures D-5 through D-28.

STOL operations between three of these city pairs were, from an economic point to view, marginal. The unfavorable STOL results projected between the Los Angeles - San Diego (Figure D-4), San Francisco - Sacramento (Figure D-10), and Detroit - Cleveland (Figure D-18) city pairs can all be attributed to short intercity distances. Poor STOL potential between San Diego and Sacramento (Figure D-12) is due to a low level of total travel demand (averaging only 1,090 daily person-trips) that is not compatible with high-density service; i.e., a minimum of four round trips per day. The Philadelphia - Washington, D.C. STOL system (Figure D-28), while attaining economic viability, also reflects the impact of travelers' preference for car transportation over short intercity distances. In that case, STOL modal split varied between only 4 and 13 percent.





1980 TOTAL INTERCITY O & D DEMAND - 76,470 DAILY PERSON TRIPS					
NOMINAL INTERCITY DISTANCE - 101 AIR MILES					
MODE	REPRESENTATIVE MODE CHARACTERISTICS				
	TIME (hrs)	COST ($)	FREQ. (dep. per hour)	No. OF PORT PAIRS SIMULATED	MODAL SPLIT W O STOL
CAR	1.40	3.52	-	6	88 %
CTOL	0.50	8.29	1.80	3	4
BUS	2.50	4.36	1.38	5	7
RAIL	2.75	4.75	0.20	1	1

Figure D-3. Los Angeles-San Diego Transportation System Intercity Characterization

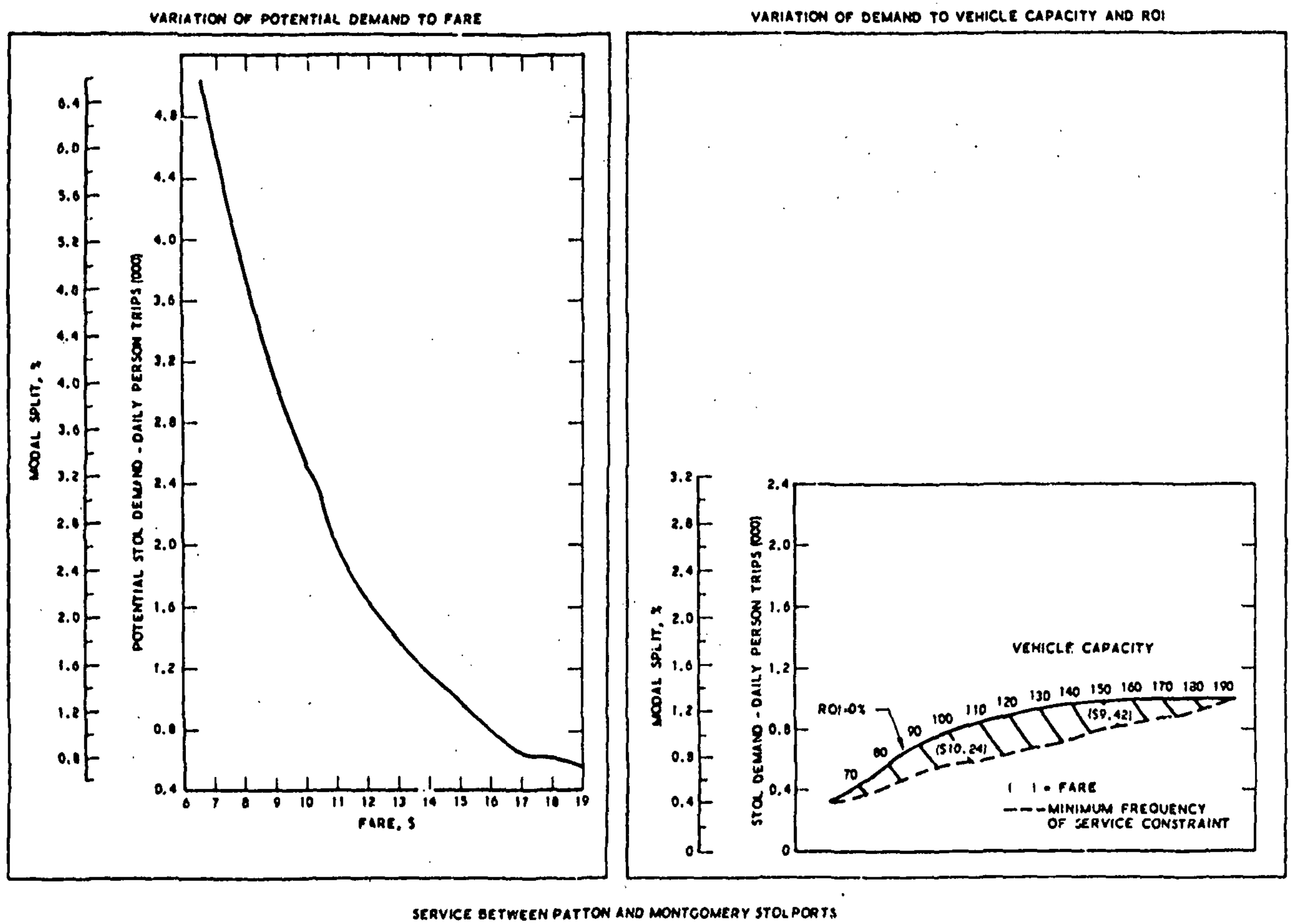
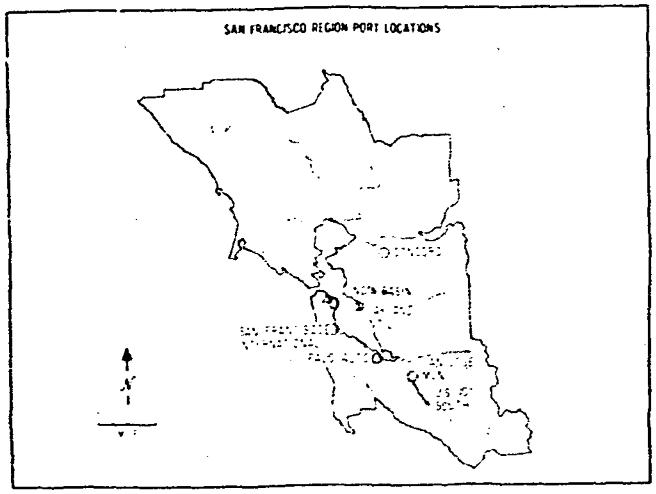
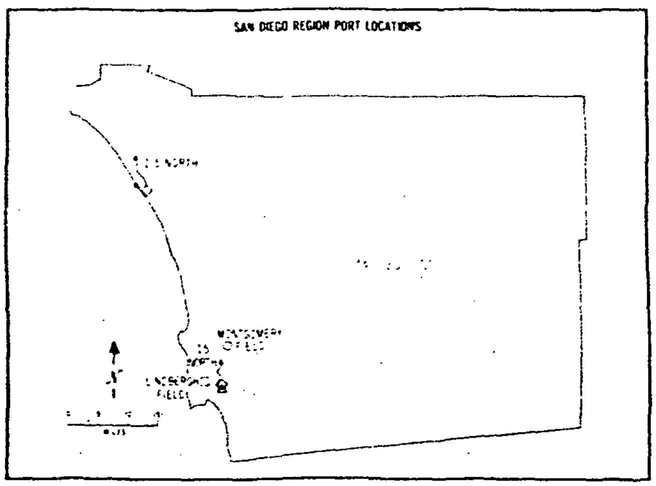


Figure D-4. Los Angeles-San Diego Transportation System STOL System Sensitivities



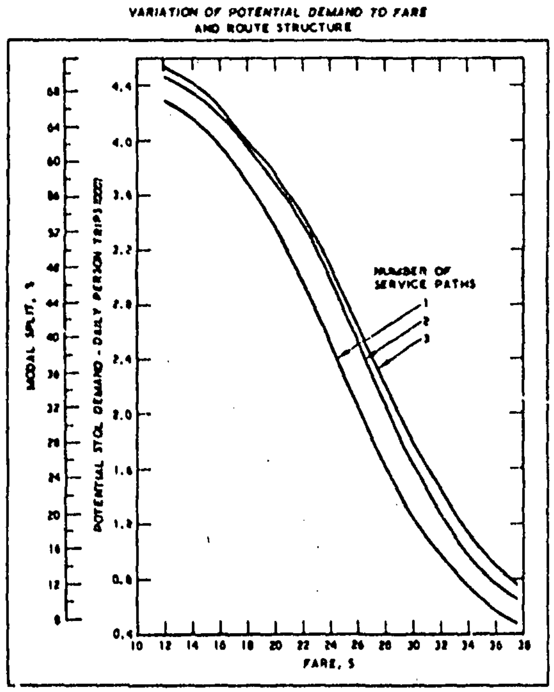


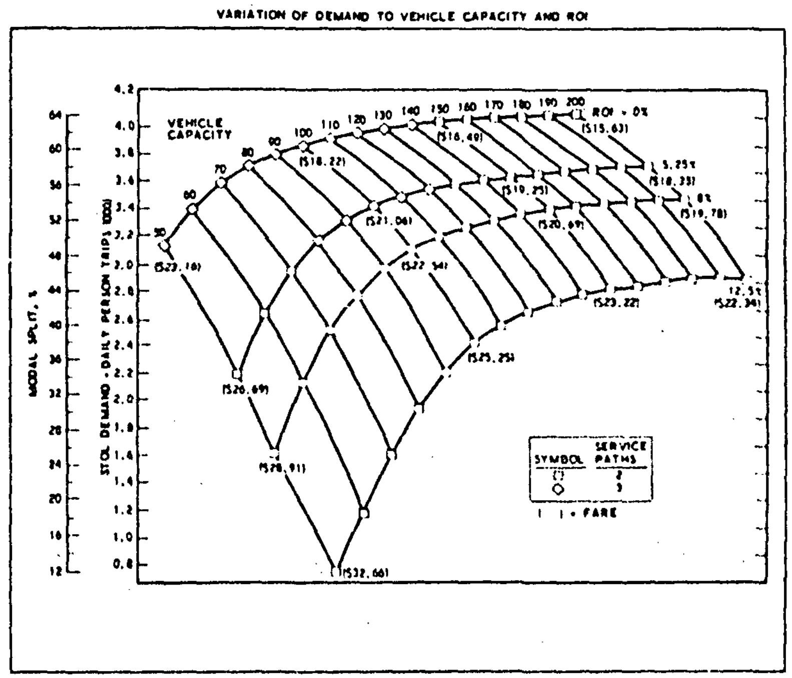
- STOL
- CTOL
- CAR
- BUS
- CBD

1980 TOTAL INTERCITY O & D DEMAND - 6408 DAILY PERSON TRIPS					
NOMINAL INTERCITY DISTANCE - 456 AIR MILES					
MODE	REPRESENTATIVE MODE CHARACTERISTICS				
	TIME (hrs)	COST ($)	FREQ. (ops. per hour)	No. OF PORT PAIRS SIMULATED	MODAL SPLIT W O STOL
CAR	8.68	19.68	-	2	52 %
CTOL	1.29*	24.50	8.62	3	46
BUS	13.00	17.40	8.69	1	2

* WEIGHTED BY ONE STOP SERVICE

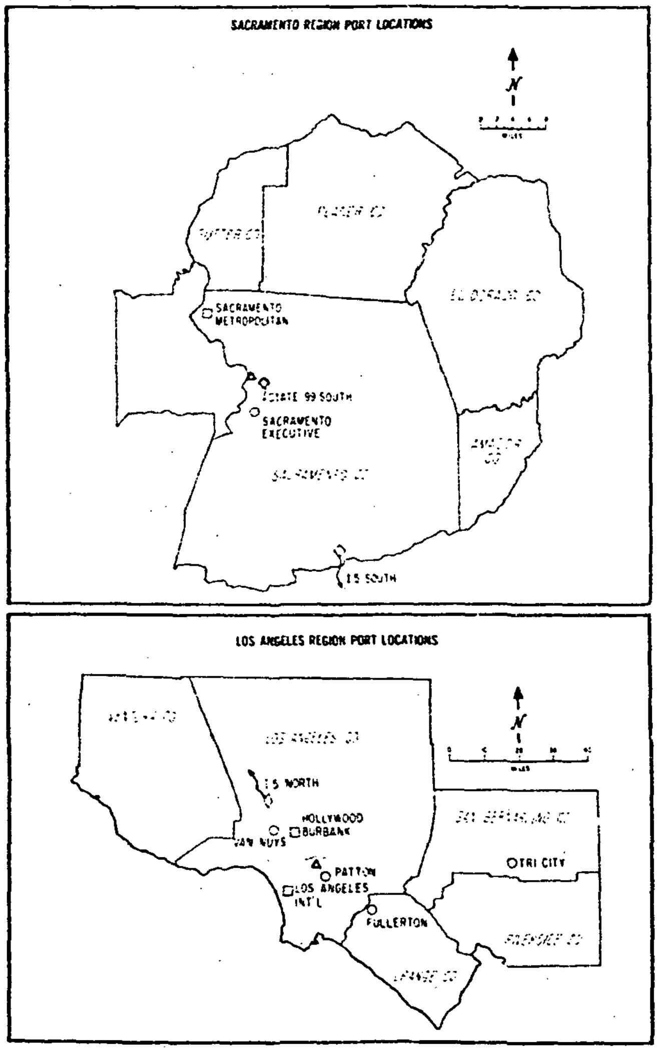
Figure D-5. San Francisco-San Diego Transportation System Intercity Characterization





STOL SERVICE PATH SET DEFINITION			
NUMBER OF SERVICE PATHS IN STOL ROUTE STRUCTURE	1	2	3
SERVICE PATH PORT LOCATIONS			
INDIA BASIN - MONTGOMERY	○	□	◇
PALO ALTO - MONTGOMERY		□	◇
CONCORD - MONTGOMERY			◇

Figure D-6. San Francisco-San Diego Transportation System STOL System Sensitivities



○ STOL
□ CTOL
◇ CAR
△ BUS
CBD

1980 TOTAL INTERCITY O & D DEMAND - 6850 DAILY PERSON TRIPS					
NOMINAL INTERCITY DISTANCE - 380 AIR MILES					
MODE	REPRESENTATIVE MODE CHARACTERISTICS				
	TIME (hrs)	COST ($)	FREQ. (dep. per hour)	No. OF PORT PAIRS SIMULATED	MODAL SPLIT W/O STOL
CAR	6.29	14.24	-	2	63 %
CTOL	1.00	18.00	1.07	2	35
BUS	9.58	12.50	0.77	1	2

Figure D-7. Sacramento-Los Angeles Transportation System Intercity Characterization

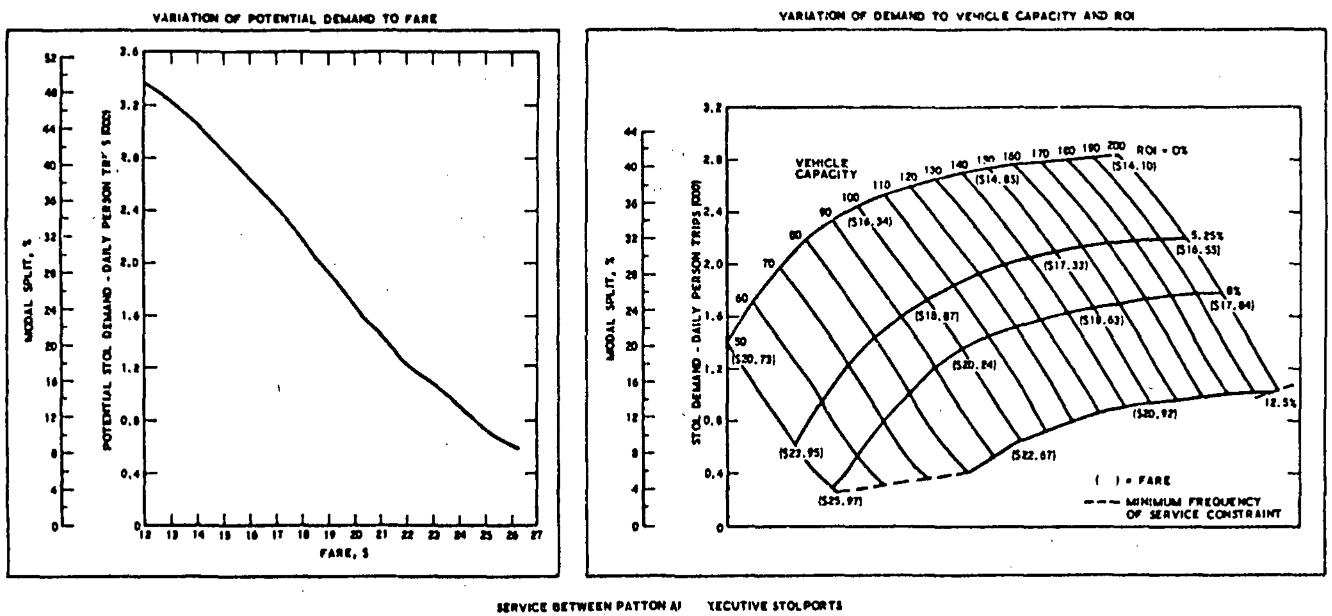
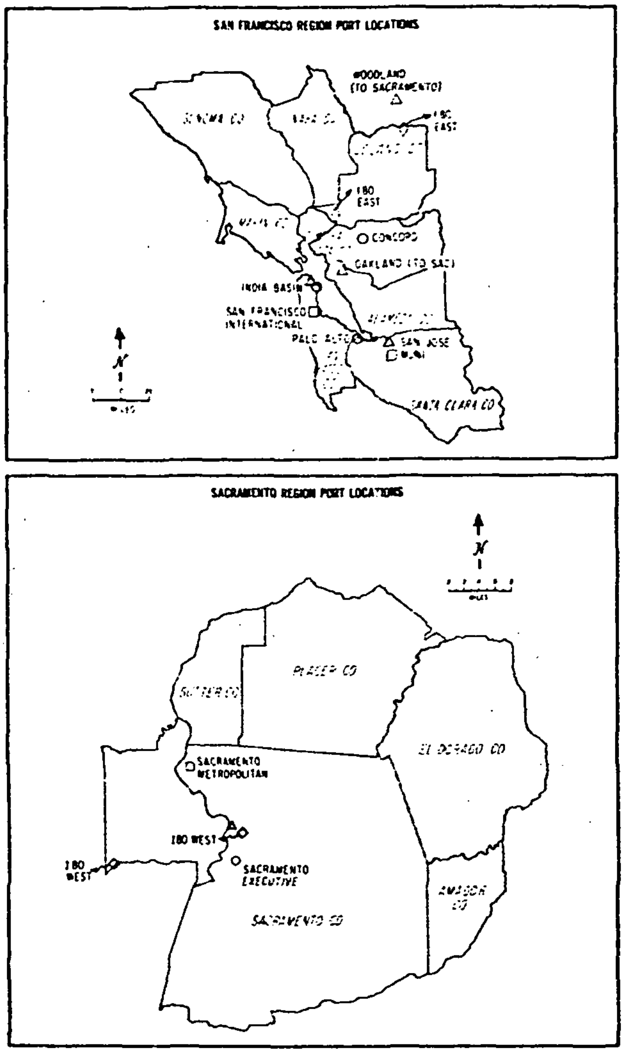


Figure D-8. Sacramento-Los Angeles Transportation System STOL System Sensitivities



○ STOL
□ CTOL
◇ CAR
△ BUS
CBD

1980 TOTAL INTERCITY O & D DEMAND -37,700 DAILY PERSON TRIPS					
NOMINAL INTERCITY DISTANCE - 79 AIR MILES					
MODE	REPRESENTATIVE MODE CHARACTERISTICS				
	TIME (hrs)	COST ($)	FREQ. (dep. per hour)	No. OF PORT PAIRS SIMULATED	MODAL SPLIT W/O STOL
CAR	1.07	2.30	-	4	93 %
CTOL	0.55	8.00	0.43	2	3
BUS	2.29	3.84	1.78	4	4

Figure D-9. San Francisco-Sacramento Transportation System Intercity Characterization

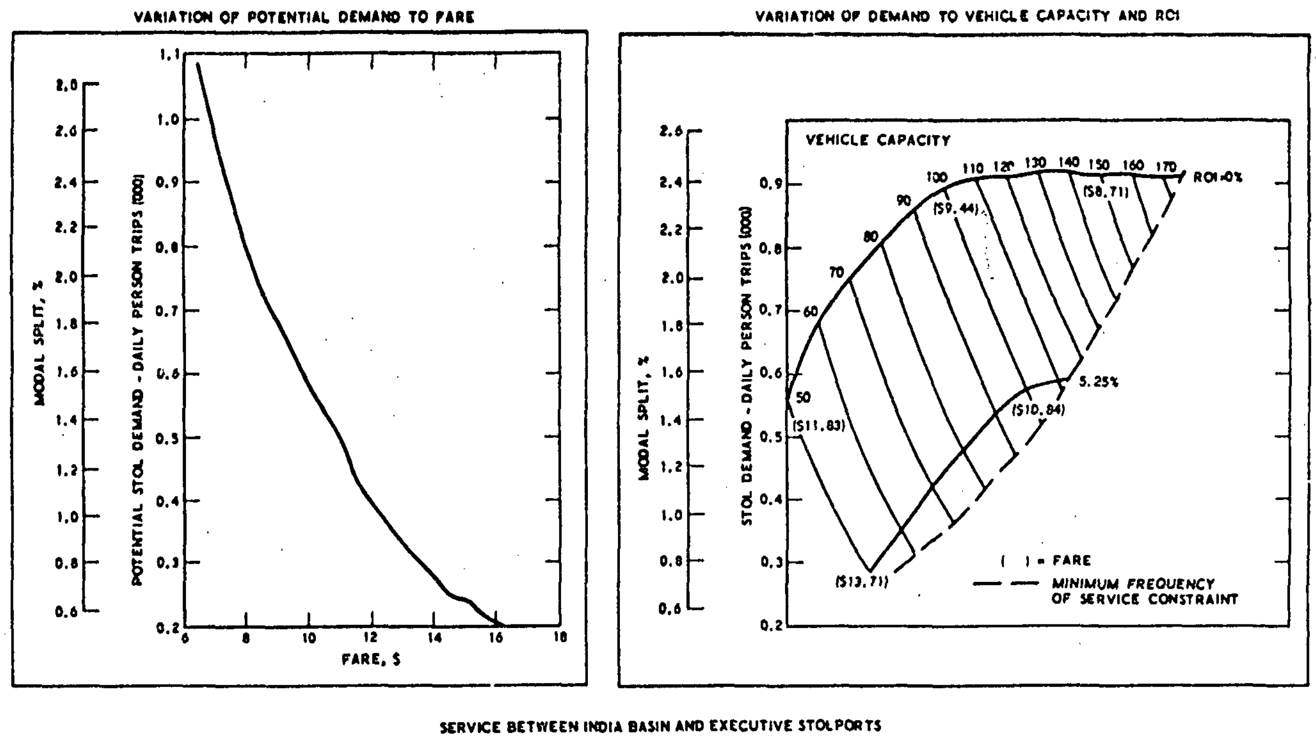
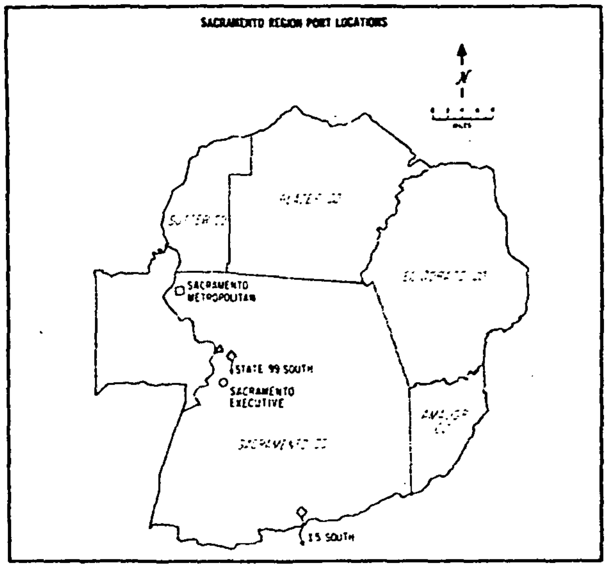
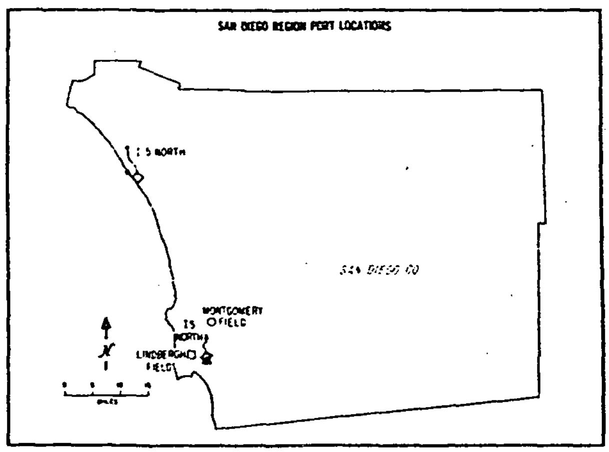


Figure D-10. San Francisco-Scaramento Transportation System STOL System Sensitivities





○ STOL
□ CTOL
◇ CAR
△ BUS
CBD

1980 TOTAL INTERCITY O & D DEMAND - 1090 DAILY PERSON TRIPS					
NOMINAL INTERCITY DISTANCE - 481 AIR MILES					
MODE	REPRESENTATIVE MODE CHARACTERISTICS				
	TIME (hrs)	COST ($)	FREQ. (dep. per hour)	No. OF PORT PAIRS SIMULATED	MODAL SPLIT W/O STOL
CAR	8.62	20.12		4	62 %
CTOL	1.67	25.00	.13	1	36
BUS	13.00	16.80	.47	1	2

Figure D-11. Sacramento-San Diego Transportation System Intercity Characterization

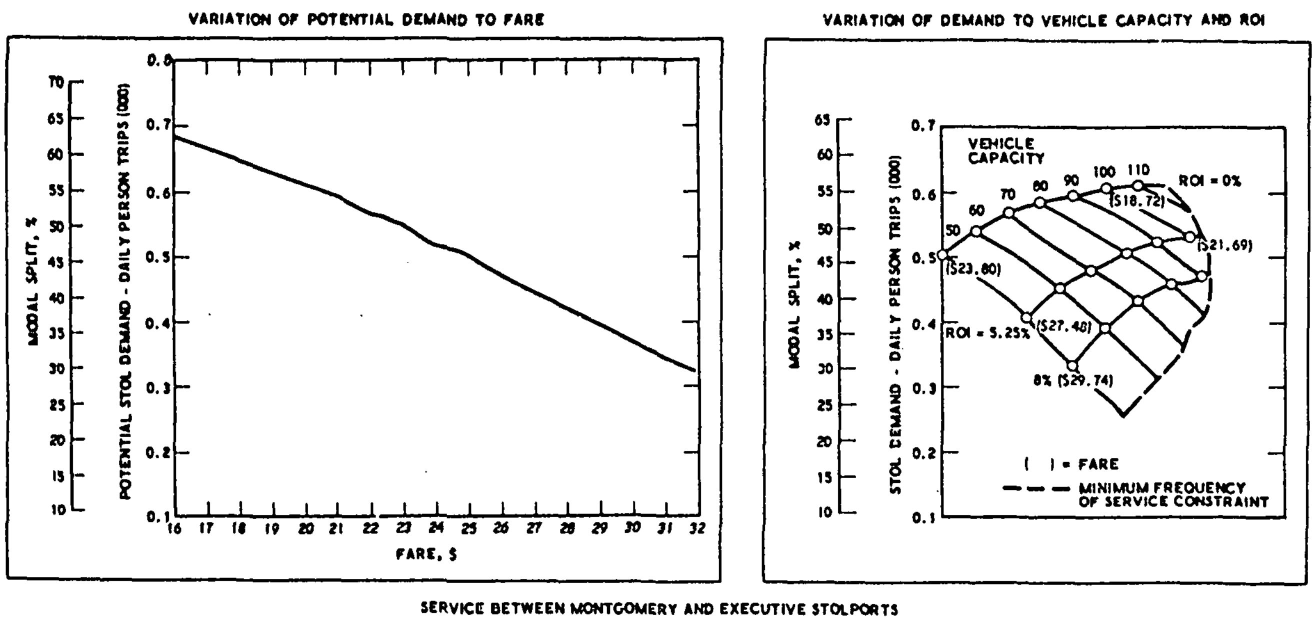
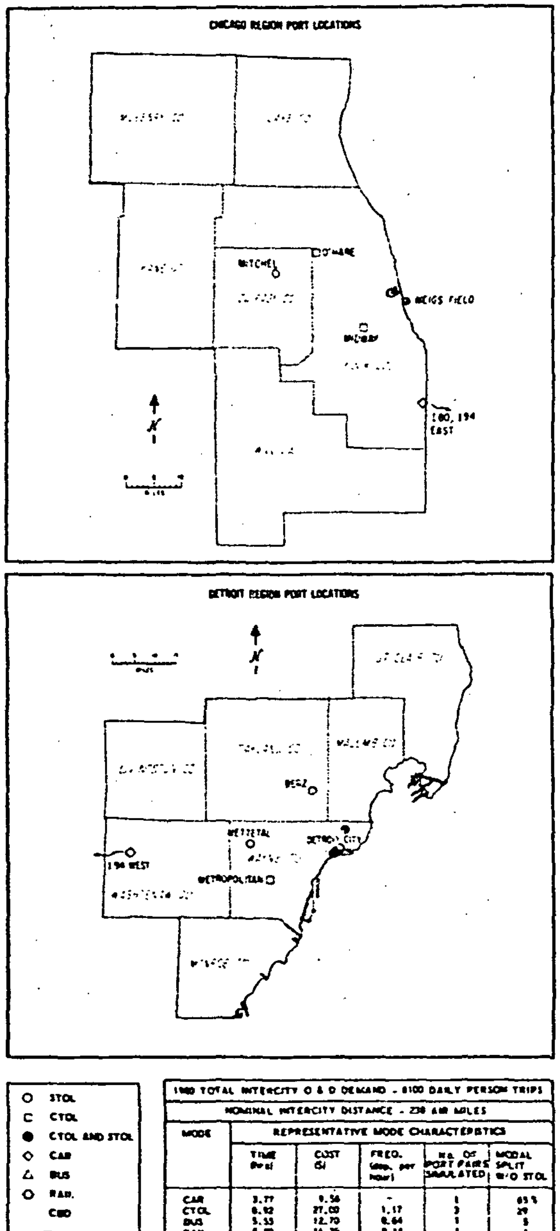
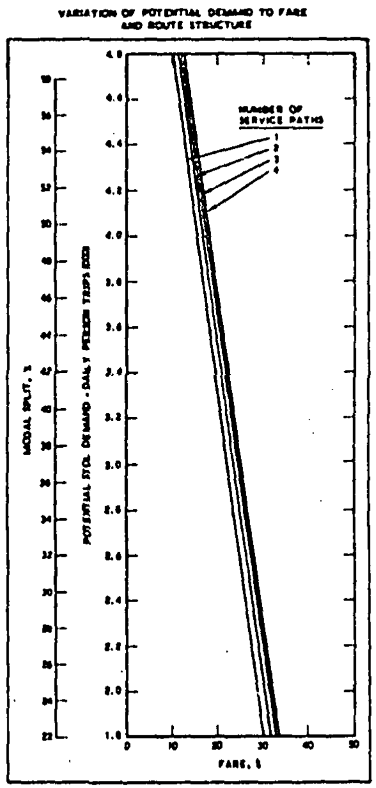


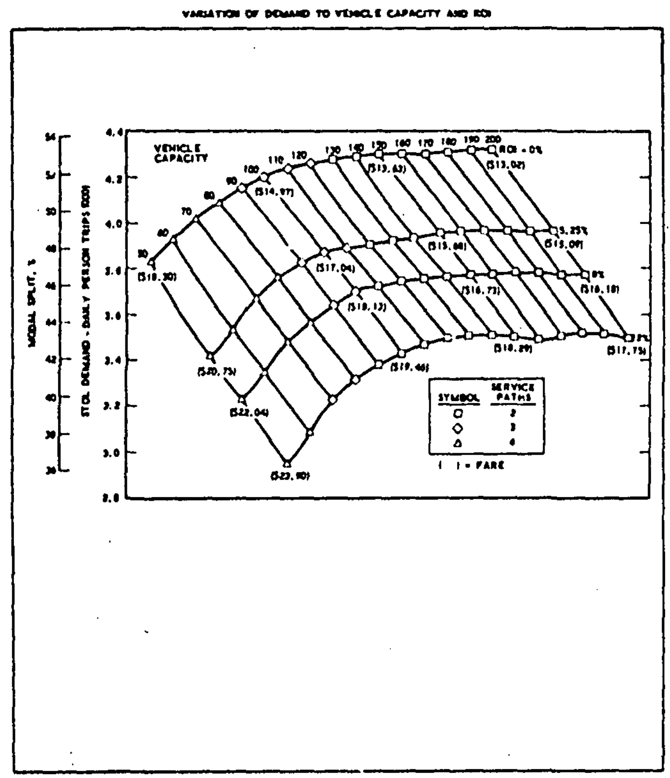
Figure D-12. Sacramento-San Diego Transportation System STOL System Sensitivities



1980 TOTAL INTERCITY O & D DEMAND - 8100 DAILY PERSON TRIPS					
NOMINAL INTERCITY DISTANCE - 238 AIR MILES					
MODE	REPRESENTATIVE MODE CHARACTERISTICS				
	TIME (hrs)	COST ($)	FREQ. (dep. per hour)	No. OF PORT PAIRS SIMULATED	MODAL SPLIT W/O STOL
CAR	3.77	9.56	-	1	65 %
CTOL	0.92	27.00	1.17	3	29
BUS	5.55	12.70	0.64	1	5
RAIL	5.50	16.25	0.14	1	1

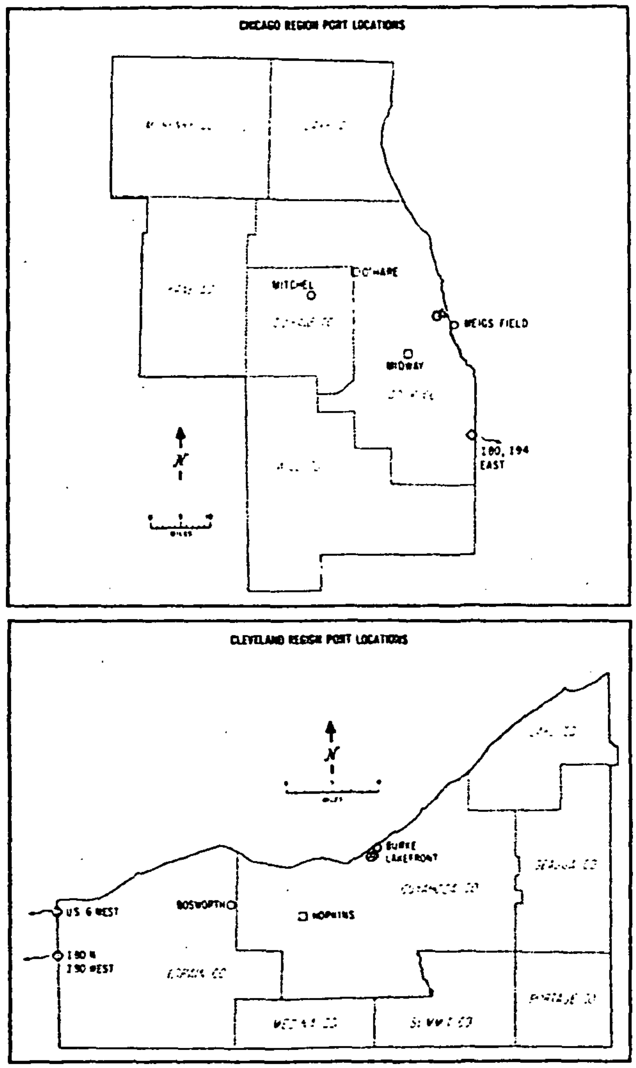
Figure D-13. Chicago-Detroit Transportation System Intercity Characterization

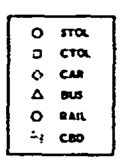




STOL SERVICE PATH SET DEFINITION				
NUMBER OF SERVICE PATHS IN STOL ROUTE STRUCTURE	1	2	3	4
SERVICE PATH PORT LOCATIONS				
MEIGS - DETROIT CITY	○	□	◇	△
MEIGS - METTETAL		□	◇	△
MITCHEL-DETROIT CITY			◇	△
MEIGS - DERZ				△

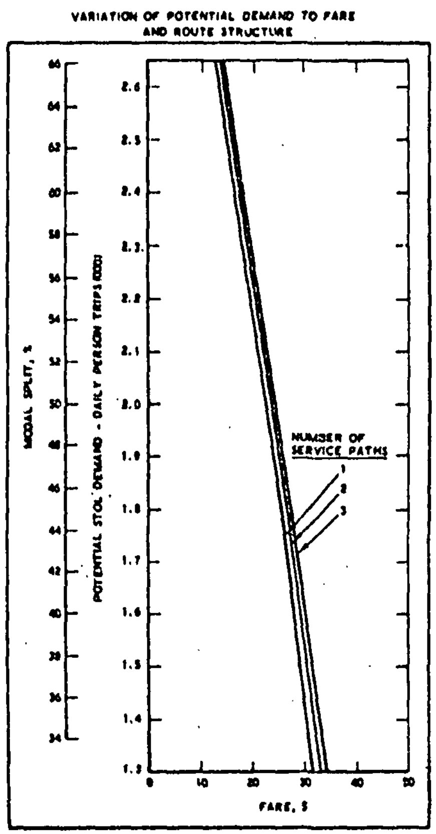
Figure D-14. Chicago-Detroit Transportation System STOL System Sensitivities

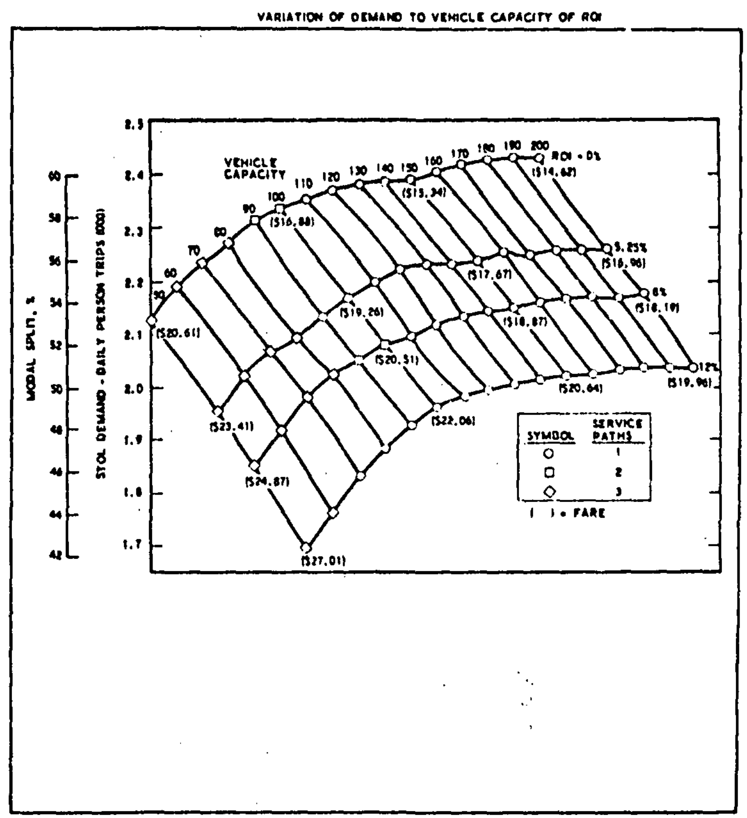




1980 TOTAL INTERCITY O & D DEMAND - 4000 DAILY PERSON TRIPS					
NOMINAL INTERCITY DISTANCE - 312 AIR MILES					
MODE	REPRESENTATIVE MODE CHARACTERISTICS				
	TIME (hrs)	COST ($)	FREQ. (dep. per hour)	No. OF PORT PAIRS SIMULATED	MODAL SPLIT W/O STOL
CAR	4.67	17.00	-	2	62 %
CTOL	1.11	33.00	.09	2	33
BUS	7.50	15.55	.78	1	3
RAIL	6.60	19.75	.07	1	2

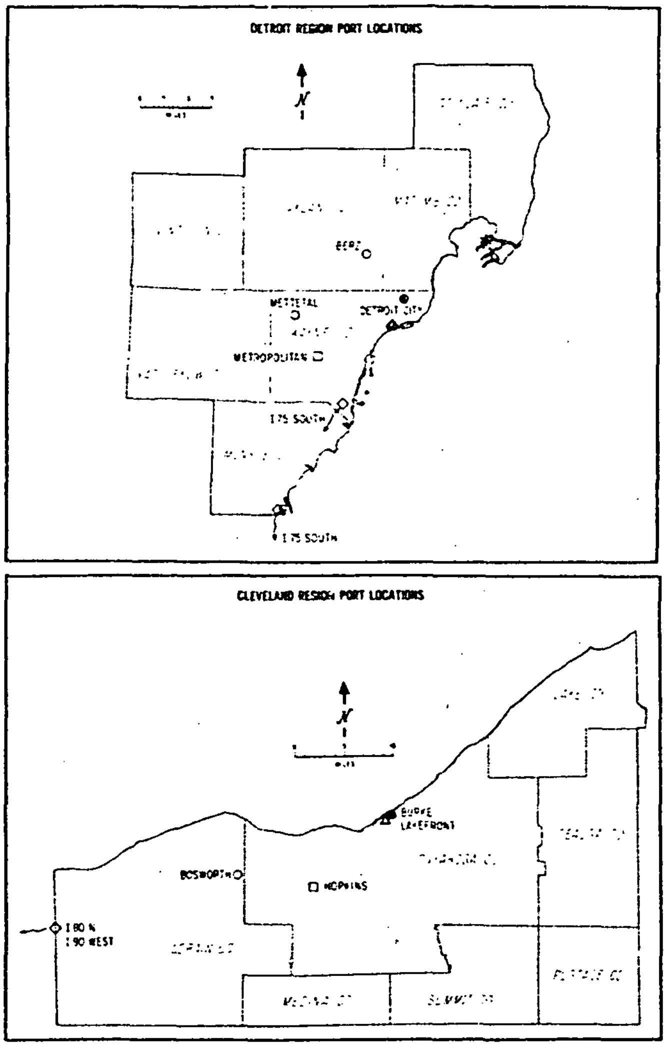
Figure D-15. Chicago-Cleveland Transportation System Intercity Characterization





STOL SERVICE PATH SET DEFINITION			
NUMBER OF SERVICE PATHS IN STOL ROUTE STRUCTURE	1	2	3
SERVICE PATH PORT LOCATIONS			
MEIGS-BURKE LAKE FRONT	○	□	◇
MITCHEL-BURKE LAKE FRONT		□	◇
MEIGS-BOSWORTH			◇

Figure D-16. Chicago-Cleveland Transportation System STOL System Sensitivities



- ○ STOL
- □ CTOL
- ● CTOL AND STOL
- ◇ CAR
- △ BUS
- CBD

1980 TOTAL INTERCITY O & D DEMAND - 4600 DAILY PERSON TRIPS					
NOMINAL INTERCITY DISTANCE - 94 AIR MILES					
MODE	REPRESENTATIVE MODE CHARACTERISTICS				
	TIME (hrs)	COST ($)	FREQ. (dep. per hour)	No. OF PORT PAIRS SIMULATED	MODAL SPLIT W/O STOL
CAR	1.76	5.48	-	2	82%
CTOL	0.58	18.00	.82	2	11
BUS	3.15	8.25	.72	1	7

Figure D-17. Detroit-Cleveland Transportation System Intercity Characterization

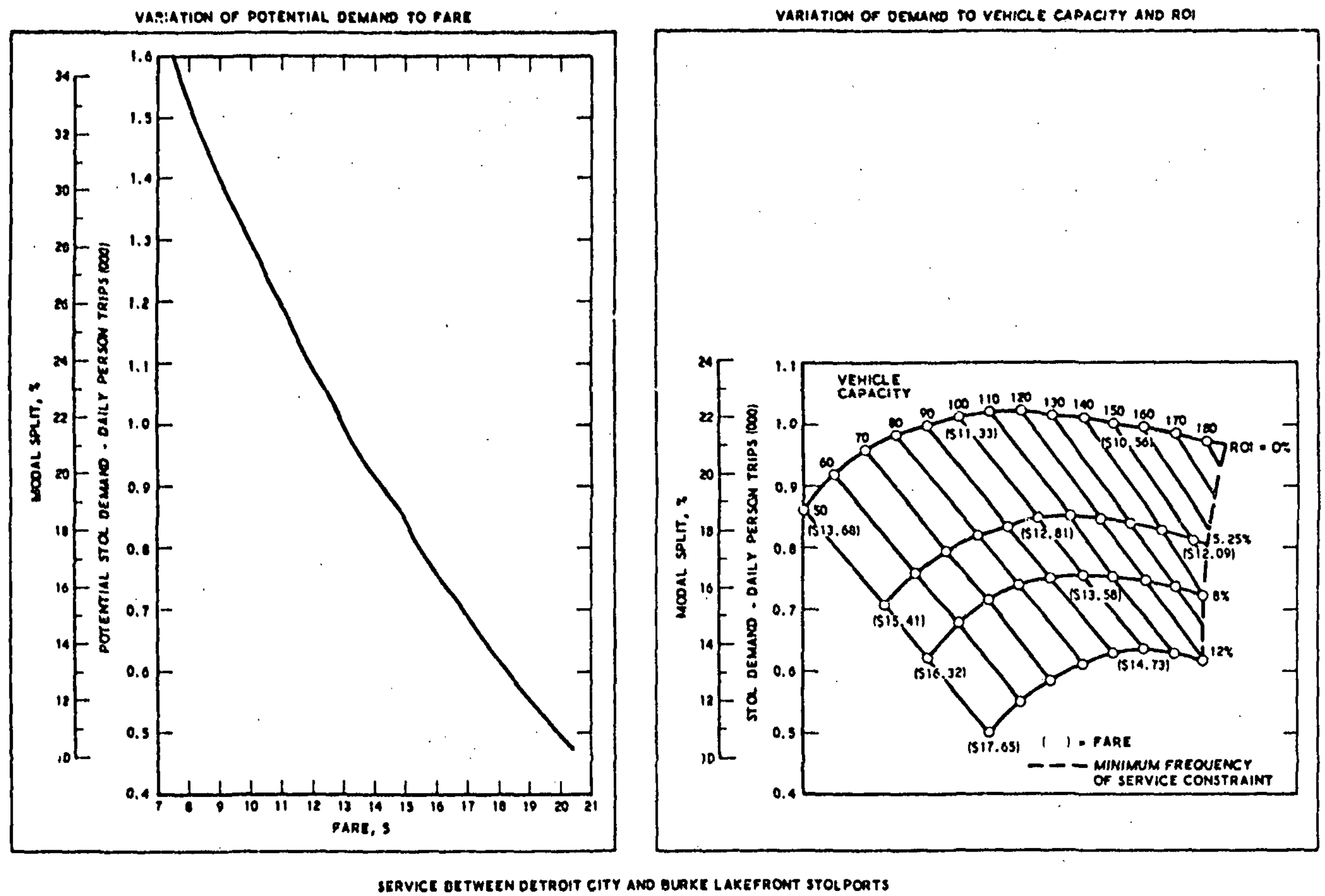
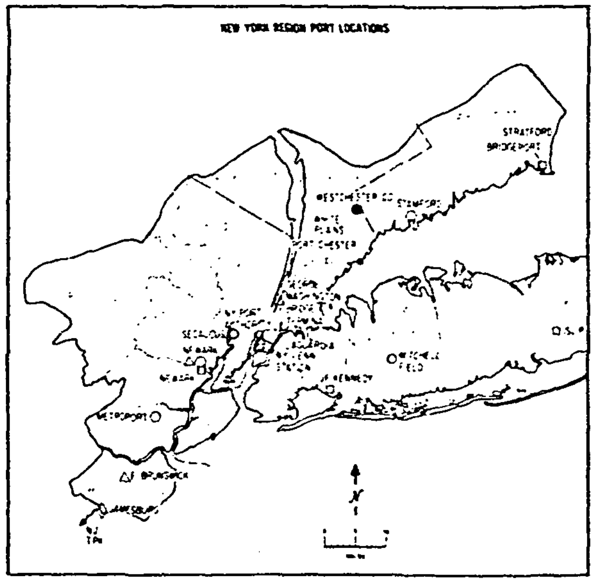
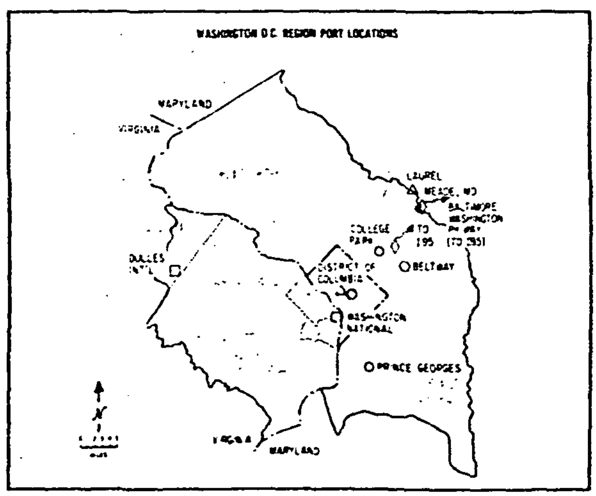


Figure D-18. Detroit-Cleveland Transportation System STOL System Sensitivities

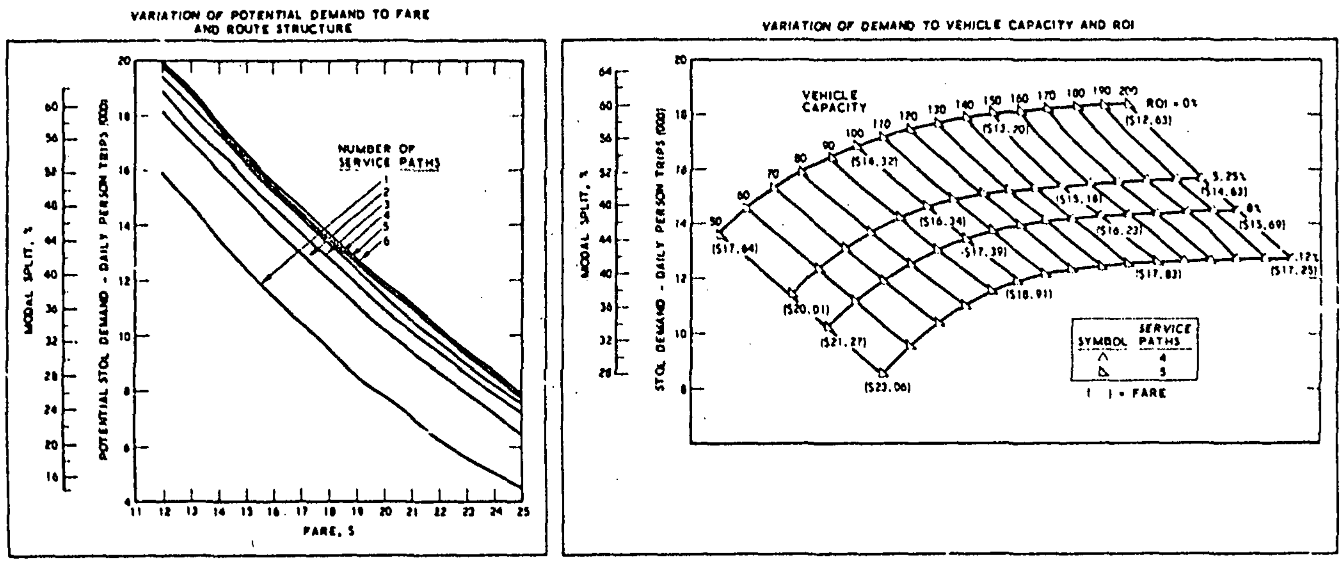




○	STOL
⊐	CTOL
●	CTOL AND STOL
◇	CAR
△	BUS
○	RAIL
	CBD

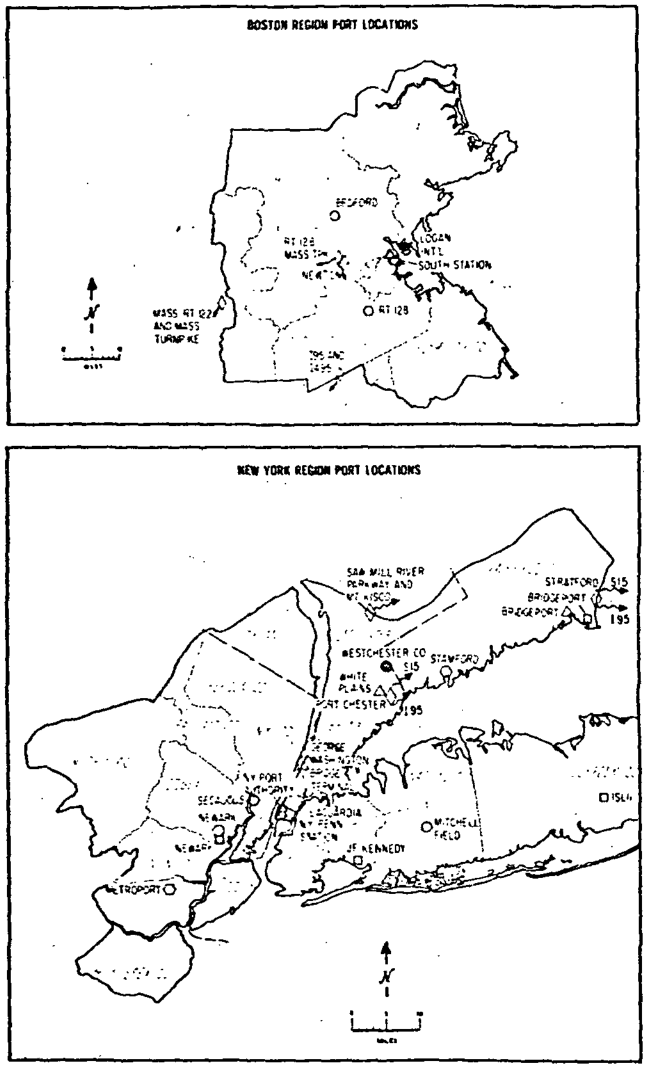
TOTAL INTERCITY O & D DEMAND - 30,560 DAILY PERSON TRIPS					
NOMINAL INTERCITY DISTANCE - 215 AIR MILES					
MODE	REPRESENTATIVE MODE CHARACTERISTICS				
	TIME (hrs)	COST ($)	FREQ. (dep. per hour)	No. OF PORT PAIRS SIMULATED	MODAL SPLIT W/O STOL
CAR	3.2	10.17	-	2	46 %
CTOL	1.02	24.10	2.36	9	21
BUS	4.05	10.95	2.62	4	8
RAIL	2.35	15.95	2.10	8	25

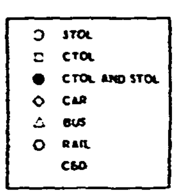
Figure D-19. New York-Washington, D.C. Transportation System Intercity Characterization



STOL SERVICE PATH SET DEFINITION						
NUMBER OF SERVICE PATHS IN STOL ROUTE STRUCTURE	1	2	3	4	5	6
SERVICE PATH PORT LOCATIONS						
SECAUCUS-COLLEGE PARK	○	□	◇	△	◺	○
MITCHELL-COLLEGE PARK		□	◇	△	◺	○
WESTCHESTER CO.-COLLEGE PARK			◇	△	◺	○
SECAUCUS-PRINCE GEORGES AIRPARK				△	◺	○
MITCHELL-PRINCE GEORGES AIRPARK					◺	○
WESTCHESTER CO.-PRINCE GEORGES AIRPARK						○

Figure D-20. New York-Washington, D. C. Transportation System STOL System Sensitivities

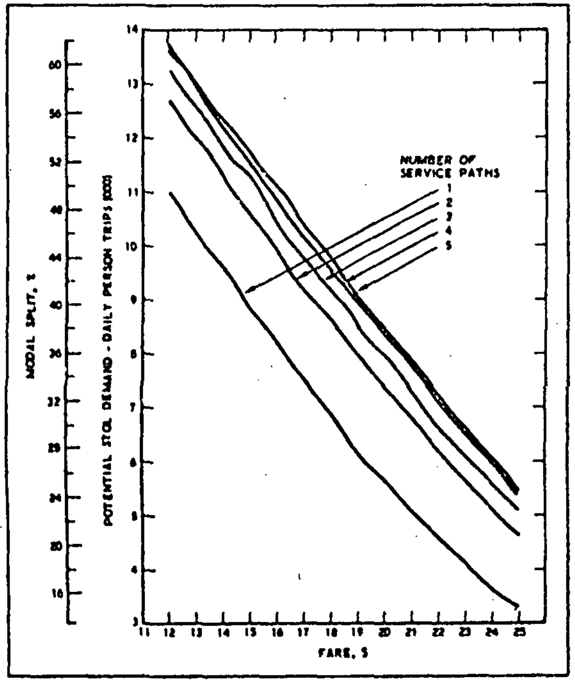




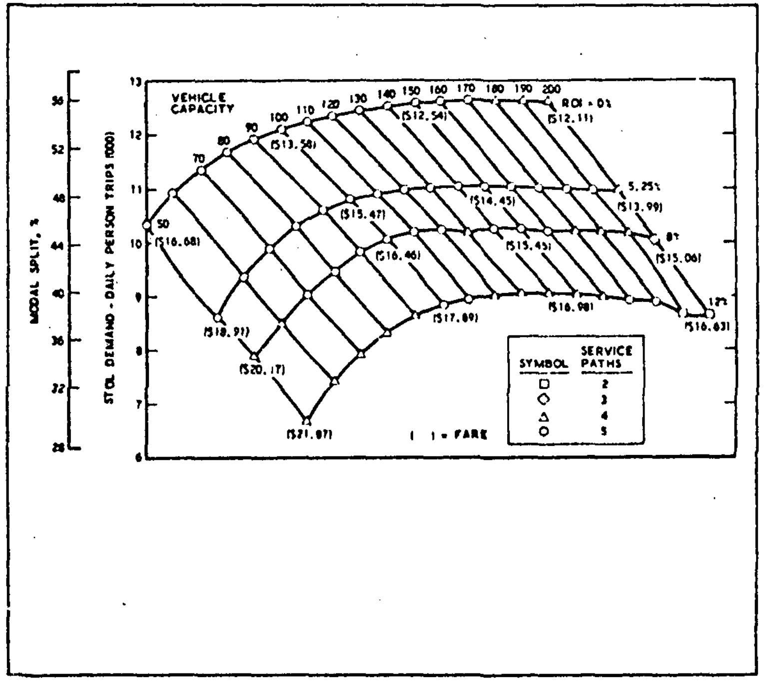
1980 TOTAL INTERCITY O & D DEMAND 22,240 DAILY PERSON TRIPS					
NOMINAL INTERCITY DISTANCE - 191 AIR MILES					
MODE	REPRESENTATIVE MODE CHARACTERISTICS				
	TIME (hrs)	COST ($)	FREQ. (dep. per hour)	No. OF PORT PAIRS SIMULATED	MODAL SPLIT W/O STOL
CAR	3.25	8.22	-	8	56 %
CTOL	0.83	22.25	2.20	6	28
BUS	4.5	9.25	2.84	8	8
RAIL	2.95	15.95	1.35	8	8

Figure D-21. New York-Boston Transportation System Intercity Characterization

VARIATION OF POTENTIAL DEMAND TO FARE AND ROUTE STRUCTURE

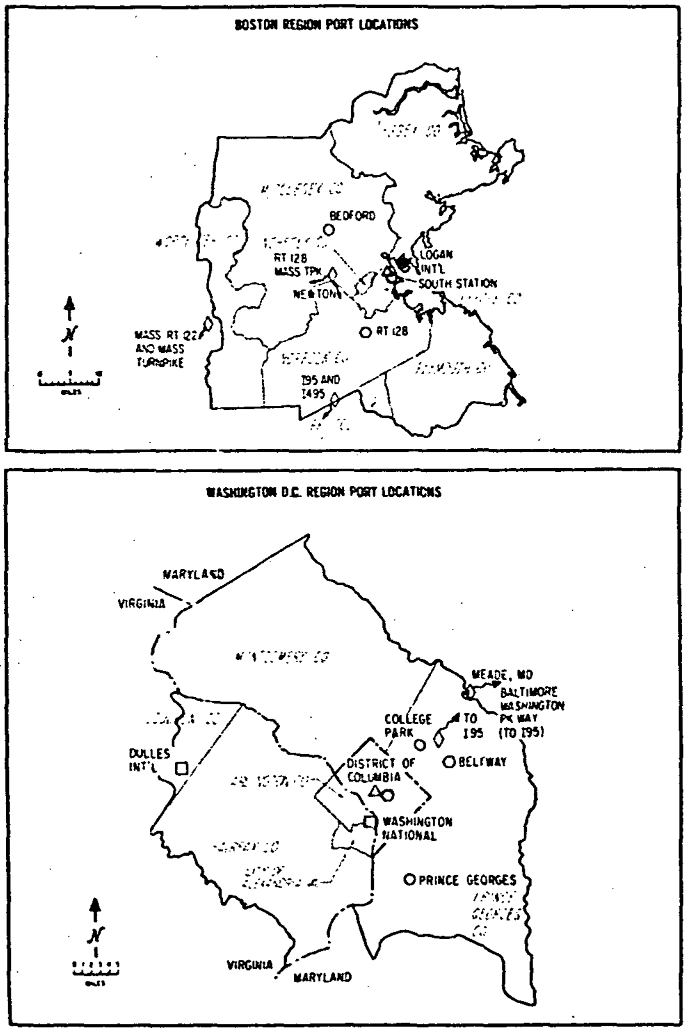


VARIATION OF DEMAND TO VEHICLE CAPACITY AND ROI



STOL SERVICE PATH SET DEFINITION					
NUMBER OF SERVICE PATHS IN STOL ROUTE STRUCTURE	1	2	3	4	5
SERVICE PATH PORT LOCATIONS					
SECAUCUS - LOGAN INT.	○	□	◇	△	○
MITCHELL - LOGAN INT.		□	◇	△	○
WESTCHESTER CO.-LOGAN INT.			◇	△	○
SECAUCUS - BEDFORD				△	○
MITCHELL - BEDFORD					○

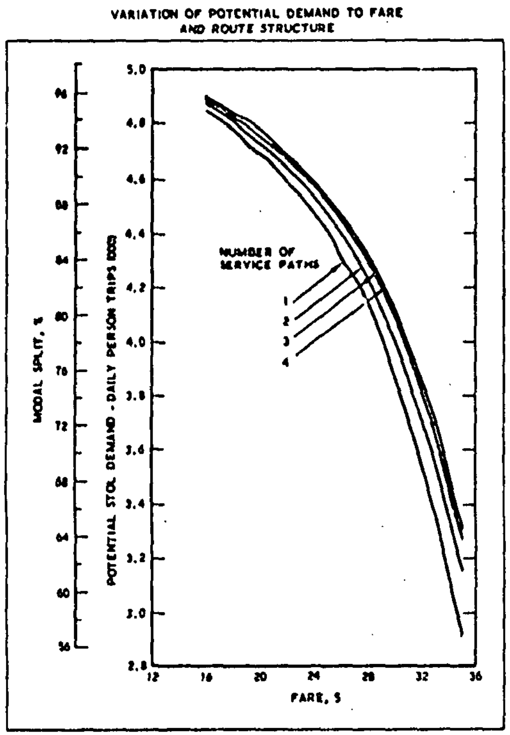
Figure D-22. New York-Boston Transportation System STOL System Sensitivities

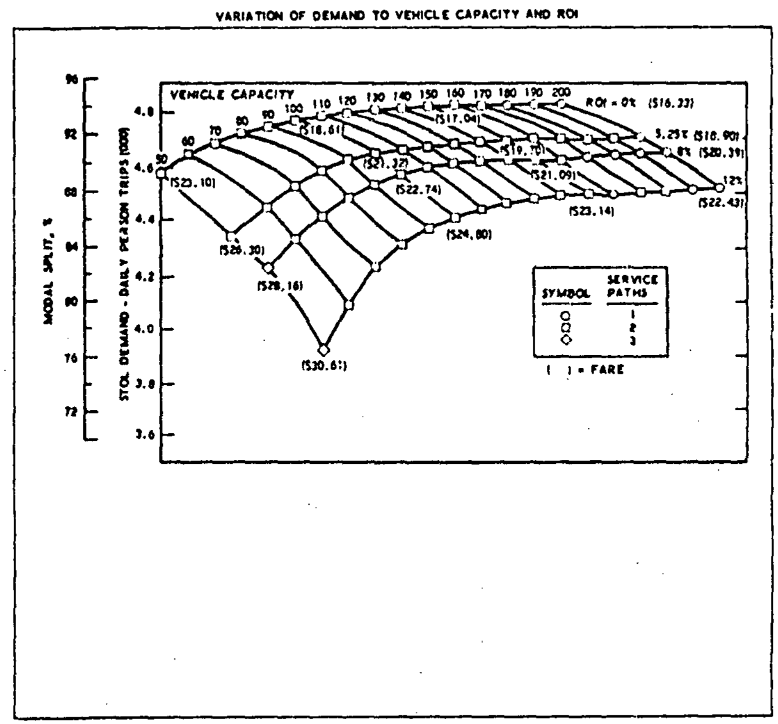


○	STOL
□	CTOL
●	CTOL AND STOL
◇	CAR
△	BUS
○	RAIL
	CBD

1980 TOTAL INTERCITY O & D DEMAND - 5,120 DAILY PERSON TRIPS					
NOMINAL INTERCITY DISTANCE - 406 AIR MILES					
MODE	REPRESENTATIVE MODE CHARACTERISTICS				
	TIME (hrs)	COST ($)	FREQ. (dep. per hour)	No. OF PORT PAIRS SIMULATED	MODAL SPLIT W/O STOL
CAR	8.47	23.79	-	6	20 %
CTOL	1.28	35.23	1.78	2	72
BUS	9.50	20.90	1.08	1	2
RAIL	5.40	30.20	1.35	4	6

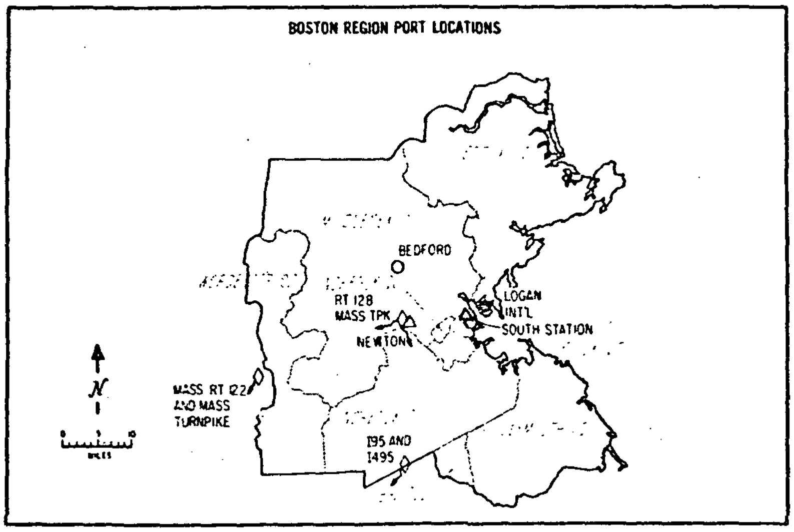
Figure D-23. Boston-Washington, D. C. Transportation System Intercity Characterization

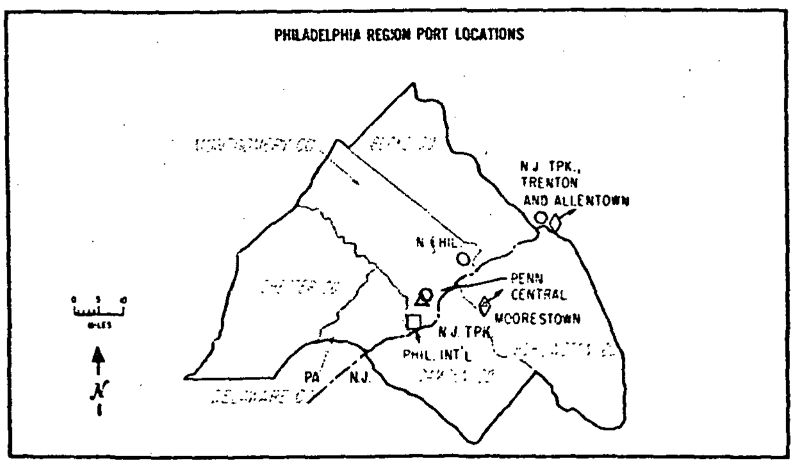




STOL SERVICE PATH SET DEFINITION				
NUMBER OF SERVICE PATHS IN STOL ROUTE STRUCTURE	1	2	3	4
SERVICE PATH PORT LOCATIONS				
LOGAN INT.-COLLEGE PARK	○	□	◇	△
BEDFORD-COLLEGE PARK		□	◇	△
LOGAN INT.-PRINCE GEORGES AIRPARK			◇	△
BEDFORD-PRINCE GEORGES AIRPARK				△

Figure D-24. Boston-Washington, D. C. Transportation System STOL System Sensitivities

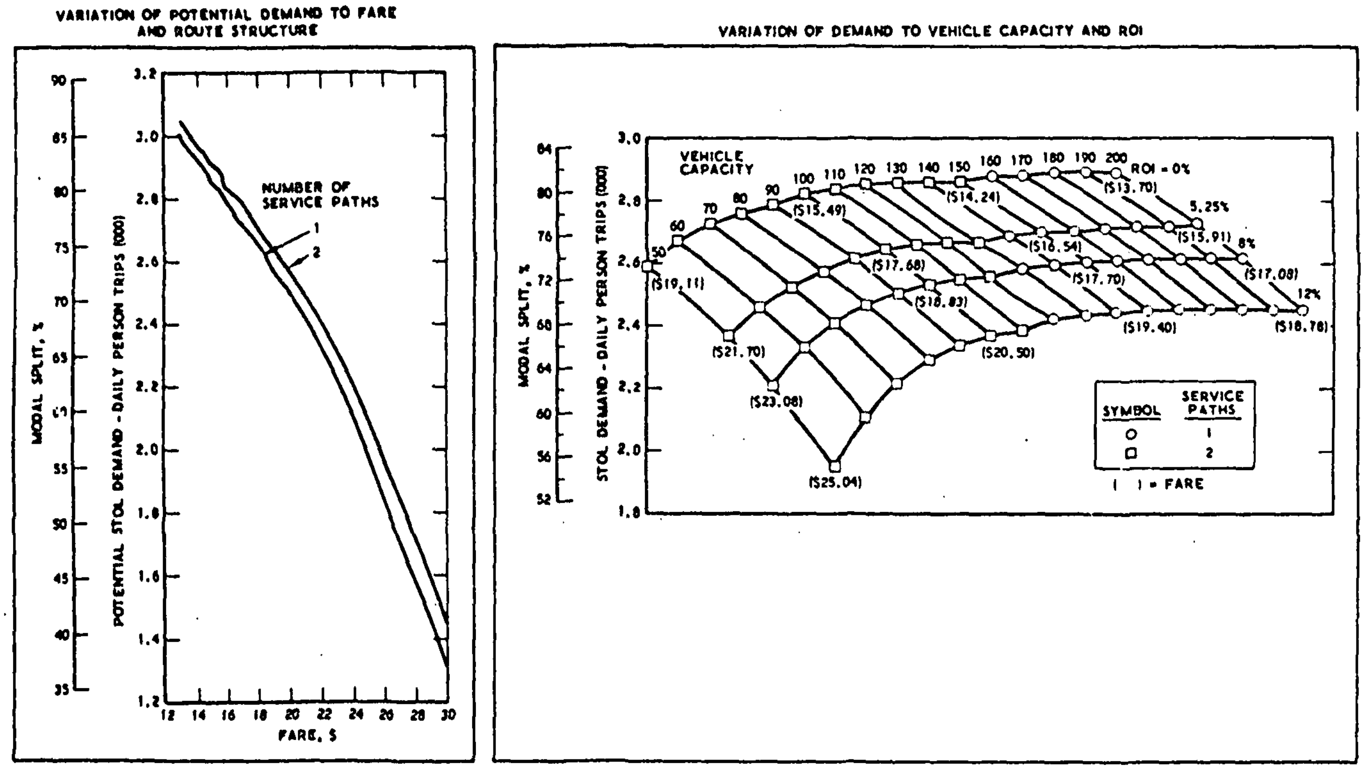




- ○ STOL
- □ CTOL
- ● CTOL AND STOL
- ◇ CAR
- △ BUS
- ○ RAIL
- CBD

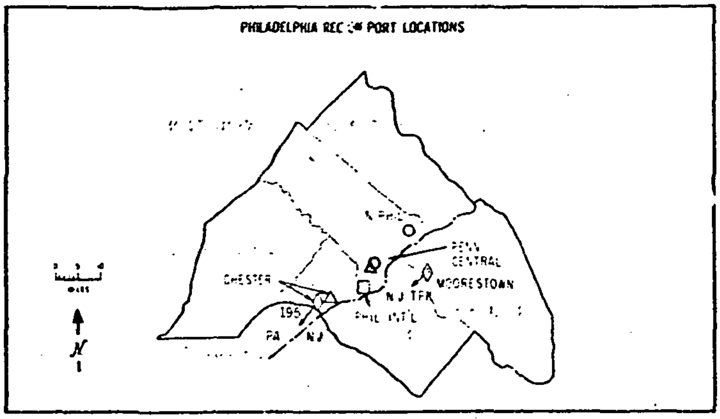
1980 TOTAL INTERCITY O & D DEMAND - 3530 DAILY PERSON TRIPS					
NOMINAL INTERCITY DISTANCE - 274 AIR MILES					
MODE	REPRESENTATIVE MODE CHARACTERISTICS				
	TIME (hrs)	COST ($)	FREQ. (dep. per hour)	No. OF PORT PAIRS SIMULATED	MODAL SPLIT W/O STOL
CAR	6.0	15.79	–	6	38 %
CTOL	1.0	28.74	1.71	1	48
BUS	7.5	14.37	1.0	2	5
RAIL	4.0	21.92	0.92	2	9

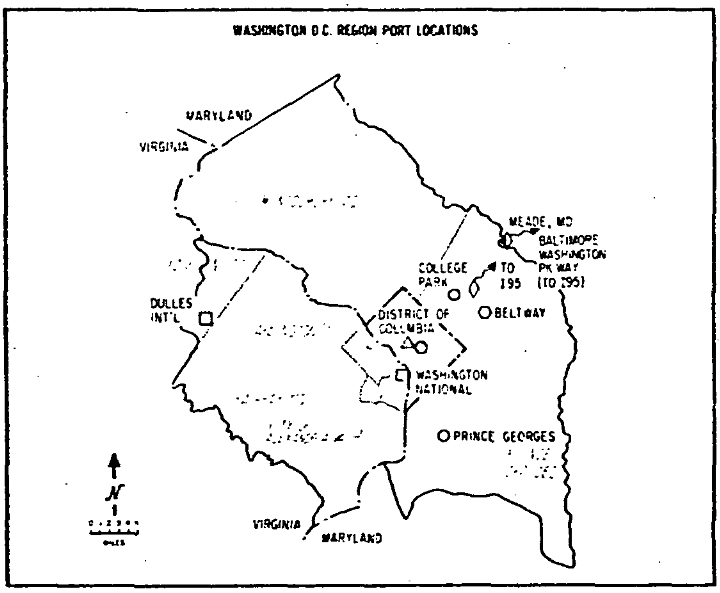
Figure D-25. Boston-Philadelphia Transportation System Intercity Characterization



STOL SERVICE PATH SET DEFINITION		
NUMBER OF SERVICE PATHS IN STOL ROUTE STRUCTURE	1	2
SERVICE PATH PORT LOCATIONS		
NORTH PHILADELPHIA-LOGAN INT	○	□
NORTH PHILADELPHIA-BEDFORD		□

Figure D-26. Boston-Philadelphia Transportation System STOL System Sensitivities

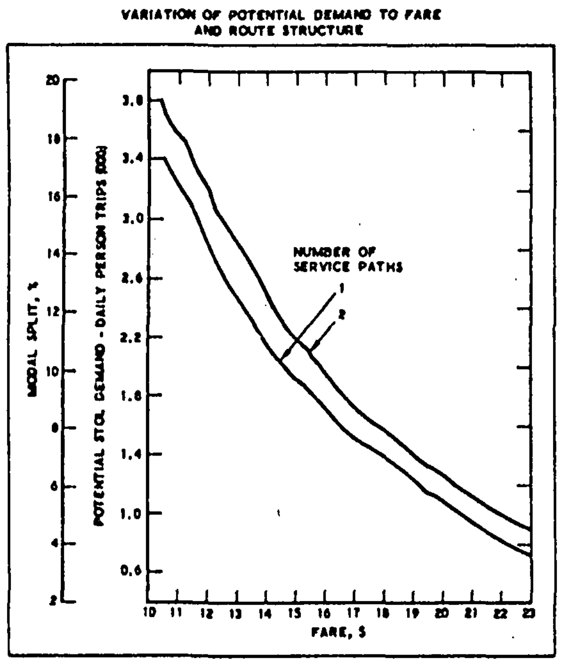


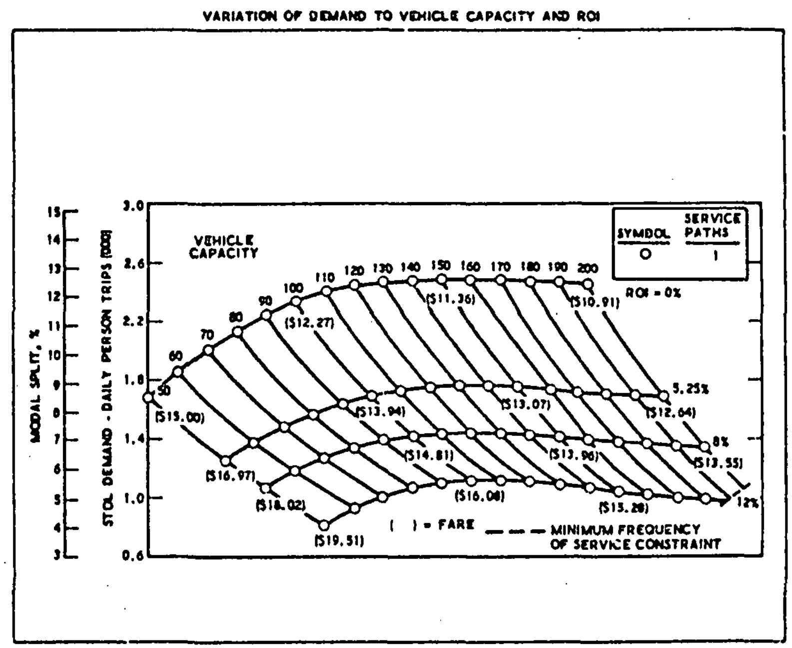


○	STOL
□	CTOL
◇	CAR
△	BUS
○	RAIL
·	CBD

TOTAL INTERCITY O & D DEMAND - 19,720 DAILY PERSON TRIPS.					
NOMINAL INTERCITY DISTANCE - 133 AIR MILES					
MODE	REPRESENTATIV MODE CHARACTERISTICS				
	TIME (hrs)	COST ($)	FREQ. (dep. per hour)	No. OF PORT PAIRS SIMULATED	MODAL SPLIT W/O STOL
CAR	1.79	5.80	-	4	76 %
CTOL	0.67	19.47	1.14	2	3
BUS	3.38	6.40	2.00	3	4
RAIL	1.48	10.20	1.55	2	17

Figure D-27. Philadelphia-Washington, D. C. Transportation System Intercity Characterization





STOL SERVICE PATH SET DEFINITION		
NUMBER OF SERVICE PATHS IN STOL ROUTE STRUCTURE	1	2
SERVICE PATH PORT LOCATIONS		
NORTH PHILADELPHIA-COLLEGE PARK	○	□
NORTH PHILADELPHIA-P.G. AIRPARK		□

Figure D-28. Philadelphia-Washington, D. C. Transportation System STOL System Sensitivities

D.3 STOL SYSTEM DEFINITION SENSITIVITIES

The selected STOL system described in Volume I (Ref. 39), Section VI. B, was based on a system that used a 150-passenger vehicle and produced an 8-percent ROI. The material presented in the tables of this section define the characteristics of STOL systems optimized for other combinations of vehicle size and ROI as listed below:

California Corridor			Midwest Triangle			Northeast Corridor		
Table No.	Vehicle Capacity (Passengers)	ROI (%)	Table No.	Vehicle Capacity (Passengers)	ROI (%)	Table No.	Vehicle Capacity (Passengers)	ROI (%)
D-5	150	8	D-12	150	8	D-19	150	8
D-6	50	8	D-13	50	8	D-20	50	8
D-7	100	8	D-14	100	8	D-21	100	8
D-8	200	8	D-15	200	8	D-22	200	8
D-9	150	0	D-16	150	0	D-23	150	0
D-10	150	5.25	D-17	150	5.25	D-24	150	5.25
D-11	150	12.5	D-18	150	12	D-25	150	12

Note: Determination of range of ROIs used in this study was based on the STOL demand potential inherent in each arena.

Table D-5. Representative STOL System Characteristics
California Corridor
150-Passenger Aircraft ROI = 8%

City Pair	Service Paths	One Way Fare $	STOL Demand Daily Person Trips		Round Trips Per Day		Fleet Size	Revenue $/day (000)	Operating Cost $/day (000)	Total Invest $M
Arena Total			11,400		58		14	201.2	172.6	156.2
LA-SF		16.28	6302		32			106.7	91.6	
	Patton-India Basin			1731		9				
	Patton-Palo Alto			1866		9				
	Fullerton-India Basin			2705		14				
SF-SD		20.69	3434		18			65.8	56.4	
	India Basin-Montgomery			2046		11				
	Palo Alto-Montgomery			1388		7				
LA-SAC		18.63	1664		8			28.7	24.6	
	Patton-Executive			1664		8				

City	Port	Annual Traffic				Capital Costs		Operating Costs	
		STOL O&D Pass (000)		STOL Ops		Airfield $(000)/yr	Terminal $(000)/yr	AF/Term $(000)/yr	Station $(000)/yr
Arena Total		8,323		85,359		9,245	8,861	1,529	4,218
Los Angeles		2,908		29,823		3,015	3,104	530	1,471
	Patton		1,920		19,695	2,700	2,051	338	963
	Fullerton		987		10,128	315	1,053	192	508
San Francisco		3,554		36,451		5,884	3,767	632	1,787
	India Basin		2,366		24,269	5,599	2,508	408	1,181
	Palo Alto		1,188		12,182	285	1,259	224	606
San Diego		1,254		12,857		296	1,326	234	638
	Montgomery		1,254		12,857	296	1,326	234	638
Sacramento		607		6,228		50	664	133	322
	Executive		607		6,228	50	664	133	322

Table D-6. Representative STOL System Characteristics
California Corridor
50-Passenger Aircraft ROI = 8%

City Pair	Service Paths	One Way Fare $	STOL Demand Daily Person Trips		Round Trips Per Day		Fleet Size	Revenue $/day (000)	Operating Cost $/day (000)	Total Invest $M
Arena Total			2546		39		9	66.7	58.4	45.[illegible]
LA-SF		25.49	293		5			6.9	6.1	
	Patton-India Basin			293		5				
SD-SAC		29.74	333		4			9.2	8.0	
	Montgomery-Executive			333		4				
SF-SD		28.91	1632		25			43.7	36.3	
	India Basin-Montgomery			996		16				
	Palo Alto-Montgomery			636		9				
LA-SAC		25.97	288		5			6.9	6.0	
	Patton-Executive			288		5				

City	Port	Annual Traffic: STOL O&D Pass (000)		Annual Traffic: STOL Ops		Capital Costs: Airfield $(000)/yr	Capital Costs: Terminal $(000)/yr	Operating Costs: AF/Term $(000)/yr	Operating Costs: Station $(000)/yr
Arena Total		1,859		57,200		8,462	2,604	532	1,236
Los Angeles		212		6,526		2,583	449	77	152
	Patton		212		6,526	2,583	449	77	152
San Francisco		703		21,630		5,650	946	205	470
	India Basin		471		14,485	5,482	497	124	306
	Palo Alto		232		7,145	168	449	81	164
San Diego		717		22,074		179	760	170	453
	Montgomery		717		22,074	179	760	170	453
Sacramento		227		6,970		50	449	80	161
	Executive		227		6,970	50	449	80	161

Table D-7. Representative STOL System Characteristics
California Corridor
100-Passenger Aircraft   ROI = 8%

City Pair	Service Paths	One Way Fare $	STOL Demand Daily Person Trips		Round Trips Per Day		Fleet Size	Revenue $/day (000)	Operating Cost $/day (000)	Total Invest $M
Arena Total			8837		65		15	170.8	148.1	124.3
LA-SF		19.87	4347		34			79.9	69.4	
	Patton-India Basin			1174		9				
	Patton-Palo Alto			1209		10				
	Fullerton-India Basin			1964		15				
SF-SD		22.54	3137		24			65.5	56.7	
	India Basin-Montgomery			1870		15				
	Palo Alto-Montgomery			1267		9				
LA-SAC		20.24	1353		10			25.4	22.0	
	Patton-Executive			1353		10				

City	Port	Annual Traffic				Capital Costs		Operating Costs	
		STOL O&D Pass (000)		STOL Ops		Airfield $(000)/yr	Terminal $(000)/yr	AF/Term $(000)/yr	Station $(000)/yr
Arena Total		6,452		99,249		8,975	6,815	1,282	3,488
Los Angeles		2,081		32,010		2,907	2,197	416	1,127
	Patton		1,364		20,980	2,646	1,435	261	730
	Fullerton		717		11,030	261	762	155	397
San Francisco		2,732		42,026		5,776	2,883	522	1,463
	India Basin		1,828		28,124	5,545	1,929	336	970
	Palo Alto		904		13,902	231	954	186	493
San Diego		1,145		17,614		242	1,201	225	617
	Montgomery		1,145		17,614	242	1,201	225	617
Sacramento		494		7,599		50	534	119	281
	Executive		494		7,599	50	534	119	281

Table D-8. Representative STOL System Characteristics
California Corridor
200-Passenger Aircraft ROI = 8%

City Pair	Service Paths	One Way Fare $	STOL Demand Daily Person Trips		Round Trips Per Day		Fleet Size	Revenue $/day (000)	Operating Cost $/day (000)	Total Invest $M
Arena Total			12,596		49		12	212.1	180.5	171.7
LA-SF		17.51	7295		28			118.2	100.8	
	Patton-India Basin			2025		8				
	Patton-Palo Alto			2162		8				
	Fullerton-India Basin			3055		12				
SF-SD		19.78	3511		14			64.3	54.5	
	India Basin-Montgomery			2110		8				
	Palo Alto-Montgomery			1401		6				
LA-SAC		17.84	1790		7			29.6	25.2	
	Patton-Executive			1790		7				

City	Port	Annual Traffic				Capital Costs		Operating Costs	
		STOL O&D Pass (000)		STOL Ops		Airfield $(000)/yr	Terminal $(000)/yr	AF/Term $(000)/yr	Station $(000)/yr
Arena Total		9,196		70,737		9,560	9,866	1,636	4,518
Los Angeles		3,316		25,510		3,141	3,564	583	1,625
	Patton		2,190		16,648	2,763	2,355	373	1,065
	Fullerton		1,126		8,662	378	1,209	210	560
San Francisco		3,945		30,342		6,010	4,208	679	1,923
	India Basin		2,637		20,283	5,662	2,813	441	1,277
	Palo Alto		1,308		10,059	348	1,395	238	646
San Diego		1,282		9,858		359	1,369	234	634
	Montgomery		1,282		9,858	359	1,369	234	634
Sacramento		653		5,027		50	725	138	336
	Executive		653		5,027	50	725	138	336

Table D-9. Representative STOL System Characteristics
California Corridor
150-Passenger Aircraft ROI = 0%

City Pair	Service Paths	One Way Fare $	STOL Demand Daily Person Trips		Round Trips Per Day		Fleet Size	Revenue $/day (000)	Operating Cost $/day (000)	Total Invest $M
Arena Total			25,111		125		29	335.9	357.1	326.6
LA-SF		14.49	16,412		54			220.2	234.1	
	Patton-India Basin			1856		9				
	Patton-Palo Alto			1407		7				
	Fullteron-India Basin			2822		15				
	Patton-Concord			3028		15				
	Tri-City-India Basin			1426		8				
	Fullerton-Palo Alto			2270		11				
	Van Nuys-India Basin			2160		11				
	Van Nuys-Palo Alto			1444		8		8.5	9.0	
LA-SD		9.42	974		5			7.4		
	Patton-Montgomery			974		5				
SF-SAC		8.71	914		4				7.8	
	India Basin-Executive			914		4				
SF-SD		16.49	4074		21			62.2	66.2	
	India Basin-Montgomery			2424		13				
	Palo Alto-Montgomery			1650		8				
LA-SAC		14.55	2737		14			37.6	40.0	
	Patton-Executive			2737		14				

City	Port	Annual Traffic				Capital Costs		Operating Costs	
		STOL O&D Pass (000)		STOL Ops		Airfield $(000)/yr	Terminal $(000)/yr	AF Term $(000)/yr	Station $(000)/yr
Arena Total		18,332		188,012		7,729	19,452	3,208	3,689
Los Angeles		7,345		75,332		3,449	7,818	1,301	3,689
	Patton		3,651		37,442	2,700	3,866	609	1,808
	Fullerton		1,858		19,061	315	1,987	329	933
	Tri-City		521		5,339	384	575	119	280
	Van Nuys		1,315		13,490	50	1,390	244	668
San Francisco		7,811		80,113		5,934	8,256	1,335	3,899
	India Basin		4,235		43,436	5,599	4,466	700	2,093
	Palo Alto		2,471		25,343	285	2,616	424	1,232
	Concord		1,105		11,334	50	1,174	211	565
San Diego		1,843		18,899		296	1,971	326	925
	Montgomery		1,843		18,899	296	1,971	326	925
Sacramento		1,333		13,668		50	1,407	246	676
	Executive		1,333		13,668	50	1,407	246	676

Table D-10. Representative STOL System Characteristics
California Corridor
150-Passenger Aircraft ROI = 5.25%

City Pair	Service Paths	One Way Fare $	STOL Demand Daily Person Trips		Round Trips Per Day		Fleet Size	Revenue $/day (000)	Operating Cost $/day (000)	Total Invest $M
Arena Total			15,806		82		19	256.0	237.0	215.4
LA-SF		17.11	10,043		52			159.0	146.1	
	Patton-India Basin			1614		8				
	Patton-Palo Alto			1138		6				
	Fullerton-India Basin			2150		11				
	Patton-Concord			2424		13				
	Tri City-India Basin			1146		6				
	Fullerton-Palo Alto			1571		8				
SF-SD		19.25	3673		19			65.5	60.1	
	India Basin-Montgomery			2187		11				
	Palo Alto-Montgomery			1486		8				
LA-SAC		17.33	2090		11			33.5	30.8	
	Patton-Executive			2090		11				

City	Port	Annual Traffic				Capital Costs		Operating Costs	
		STOL O&D Pass (000)		STOL Ops		Airfield $(000)/yr	Terminal $(000)/yr	AF/Term $(000)/yr	Station $(000)/yr
Arena Total		11,539		118,341		9,679	12,259	2,107	5,838
Los Angeles		4,428		45,421		3,399	4,712	806	2,239
	Patton		2,652		27,200	2,700	2,801	453	1,320
	Fullerton		1,358		13,931	315	1,434	250	689
	Tri-City		418		4,290	384	477	103	230
San Francisco		5,007		51,348		5,934	5,308	896	2,521
	India Basin		2,591		26,572	5,599	2,739	443	1,290
	Palo Alto		1,531		15,703	285	1,621	277	773
	Concord		885		9,073	50	948	176	458
San Diego		1,341		13,750		296	1,416	248	680
	Montgomery		1,341		13,750	296	1,416	248	680
Sacramento		763		7,822		50	823	157	398
	Executive		763		7,822	50	823	157	398

Table D-11. Representative STOL System Characteristics
California Corridor
150-Passenger Aircraft ROI = 12.5%

City Pair	Service Paths	One Way Fare $	STOL Demand Daily Person Trips		Round Trips Per Day		Fleet Size	Revenue $/day (000)	Operating Cost $/day	Total Invest $...
Arena Total			5748		30		7	116.7	90.7	80.8
LA-SF		20.53	1954		10			37.1	28.9	
	Patton-India Basin			1954		10				
SF-SD		23.22	2853		15			61.4	47.6	
	India Basin-Montgomery			1736		9				
	Palo Alto-Montgomery			1117		6				
LA-SAC		20.92	941		5			18.2	14.2	
	Patton-Executive			941		5				

City	Port	Annual Traffic				Capital Costs		Operating Costs	
		STOL O&D Pass (000)		STOL Ops		Airfield $(000)/yr	Terminal $(000)/yr	AF/Term $(000)/yr	Station $(000)/yr
Arena Total		4,197		43,041		8,930	4,607	847	2,178
Los Angeles		1,057		10,838		2,700	1,124	203	542
	Patton		1,057		10,838	2,700	1,124	203	542
San Francisco		1,755		17,997		5,884	1,898	351	908
	India Basin		1,347		13,815	5,599	1,422	249	683
	Palo Alto		408		4,182	285	476	102	225
San Diego		1,042		10,683		296	1,109	201	534
	Montgomery		1,042		10,683	296	1,109	201	534
Sacramento		343		3,523		50	476	92	194
	Executive		343		3,523	50	476	92	194

Table D-12. Representative STOL System Characteristics
Midwest Triangle
150-Passenger Aircraft ROI = 8%

City Pair	Service Paths	One Way Fare $	STOL Demand Daily Person Trips		Round Trips Per Day		Fleet Size	Revenue $/day (000)	Operating Cost $/day (000)	Total Invest $M
Arena Total			5921		31		6	96.0	83.0	71.2
CHI-DET		16.73	3770		20			58.4	50.5	
	Meigs-Detroit City			2199		12				
	Meigs-Mettetal			1571		8				
CHI-CLV		18.87	2151		11			37.6	32.5	
	Meigs-Burke Lakefront			2151		11				

City	Port	Annual Traffic				Capital Costs		Operating Costs	
		STOL O&D Pass (000)		STOL Ops		Airfield $(000)/yr	Terminal $(000)/yr	AF/Term $(000)/yr	Station $(000)/yr
Arena Total		4,322		44,332		582	4,637	828	4,277
Chicago		2,161		22,166		72	2,298	376	2,272
	Meigs		2,161		22,166	72	2,298	376	2,272
Cleveland		785		8,054		0	846	161	743
	Burke Lakefront		785		8,054	0	846	161	743
Detroit		1,376		14,112		510	1,493	291	1,262
	Detroit City		802		8,231	126	864	163	763
	Mettetal		574		5,881	384	629	128	499

Table D-13. Representative STOL System Characteristics Midwest Triangle 50-Passenger Aircraft ROI = 8%

City Pair	Service Paths	One Way Fare $	STOL Demand Daily Person Trips		Round Trips Per Day		Fleet Size	Revenue $/day (000)	Operating Cost $/day (000)	Total Invest $M
Arena Total			5694		88		16	117.7	103.2	79.5
CHI-DET		22.04	3223		50			65.7	57.6	
	Meigs-Detroit City			657		10				
	Meigs-Mettetal			849		13				
	Mitchel-Detroit City			939		15				
	Meigs-Berz			778		12				
CHI-CLV		24.87	1849		28			42.6	37.3	
	Meigs-Burke Lakefront			827		13				
	Mitchel-Burke Lakefront			601		9				
	Meigs-Bosworth			421		6				
DET-CLV		16.32	622		10			9.4	8.3	
	Detroit City-Burke Lakefront			622		10				

City	Port	Annual Traffic				Capital Costs		Operating Costs	
		STOL O&D Pass (000)		STOL Ops		Airfield $(000)/yr	Terminal $(000)/yr	AF/Term $(000)/yr	Station $(000)/yr
Arena Total		4,156		127,678		1,068	4,937	1,029	4,166
Chicago		1,851		56,950		267	1,939	416	2,021
	Meigs		1,289		39,659	0	1,349	275	1,468
	Mitchel		562		17,291	267	590	141	553
Cleveland		902		27,748		[illegible]	1,243	241	849
	Burke Lakefront		748		23,021	0	794	175	789
	Bosworth		154		4,727	267	449	66	60
Detroit		1,403		43,180		534	1,755	372	1,296
	Detroit City		810		24,911	0	857	187	867
	Mettetal		310		9,531	267	449	95	231
	Bers		283		8,738	267	449	90	198

Table D-14. Representative STOL System Characteristics
Midwest Triangle
100-Passenger Aircraft ROI = 8%

City Pair	Service Paths	One Way Fare $	STOL Demand Daily Person Trips		Round Trips Per Day		Fleet Size	Revenue $/day (000)	Operating Cost $/day (000)	Total Invest $M
Arena Total			6538		50			111.1	97.0	77.1
CHI-DET		18.13	3701		28			62.1	54.3	
	Meigs-Detroit City			1311		10				
	Meigs-Mettetal			1251		9				
	Mitchel-Detroit City			1139		9				
CHI-CLV		20.51	2081		16			39.5	34.4	
	Meigs-Burke Lakefront			1314		10				
	Mitchel-Burke Lakefront			767		6				
DET-CLV		13.58	756		6			9.5	8.3	
	Detroit City-Burke Lakefront			756		6				

City	Port	*Annual Traffic*				*Capital Costs*		*Operating Costs*	
		STOL O&D Pass (000)		STOL Ops		Airfield $(000)/yr	Terminal $(000)/yr	AF/Term $(000)/yr	Station $(000)/yr
Arena Total		4,773		73,429		747	5,058	970	1,827
Chicago		2,110		32,468		348	2,246	421	2,165
	Meigs		1,415		21,765	18	1,505	269	1,502
	Mitchel		695		10,703	330	741	152	663
Cleveland		1,036		15,933		0	1,089	207	1,063
	Burke Lakefront		1,036		15,933	0	1,089	207	1,063
Detroit		1,627		25,028		399	1,723	342	1,599
	Detroit City		1,170		18,003	69	1,227	229	1,219
	Mettetal		457		7,025	330	496	113	380

Table D-15. Representative STOL System Characteristics Midwest Triangle 200-Passenger Aircraft ROI = 8%

City Pair	Service Paths	One Way Fare $	STOL Demand Daily Person Trips		Round Trips Per Day		Fleet Size	Revenue $/day (000)	Operating Cost $/day (000)	Total Invest $M
Arena Total			5952		23		5	93.2	80.0	72.0
CHI-DET		16.18	3775		15			56.5	48.6	
	Meigs-Detroit City			2221		9				
	Meigs-Mettetal			1554		6				
CHI-CLV		18.19	2177		8			36.7	31.4	
	Meigs-Burke Lakefront			2177		8				

City	Port	Annual Traffic: STOL O&D Pass (000)		Annual Traffic: STOL Ops		Capital Costs: Airfield $(000)/yr	Capital Costs: Terminal $(000)/yr	Operating Costs: AF/Term $(000)/yr	Operating Costs: Station $(000)/yr
Arena Total		4,346		33,423		812	4,728	817	4,233
Chicago		2,173		16,712		126	2,337	370	2,250
	Meigs		2,173		16,712	126	2,337	370	2,250
Cleveland		795		6,112		58	869	160	741
	Burke Lakefront		795		6,112	58	869	160	741
Detroit		1,378		10,599		628	1,522	287	1,242
	Detroit City		811		6,236	181	886	162	759
	Mettetal		567		4,363	447	636	125	483

Table D-16. Representative STOL System Characteristics Midwest Triangle 150-Passenger Aircraft ROI = 0%

City Pair	Service Paths	One Way Fare $	STOL Demand Daily Person Trips		Round Trips Per Day		Fleet Size	Revenue $/day (000)	Operating Cost $/day (000)	Total Invest $M
Arena Total			7688		40		8	97.9	102.7	85.9
CHI-DET		13.63	4297		22			54.2	57.4	
	Meigs-Detroit City			2488		13				
	Meigs-Mettetal			1809		9				
CHI-CLV		15.34	2390		13			33.9	36.0	
	Meigs-Burke Lakefront			2390		13				
DET-CLV		10.56	1001		5			9.8	10.3	
	Detroit City-Burke Lakefront			1001		5				

City	Port	Annual Traffic				Capital Costs		Operating Costs	
		STOL O&D Pass (000)		STOL Ops		Airfield $(000)/yr	Terminal $(000)/yr	AF/Term $(000)/yr	Station $(000)/yr
Arena Total		5,612		57,562		582	5,960	1,030	5,722
Chicago		2,441		25,033		72	2,585	420	2,569
	Meigs		2,441		25,033	72	2,585	420	2,569
Cleveland		1,238		12,695		0	1,310	232	1,257
	Burke Lakefront		1,238		12,695	0	1,310	232	1,257
Detroit		1,933		19,894		510	2,065	378	1,896
	Detroit City		1,273		13,061	126	1,347	237	1,297
	Mettetal		660		6,773	384	718	141	599

Table D-17. Representative STOL System Characteristics
Midwest Triangle
150-Passenger Aircraft ROI = 5.25%

City Pair	Service Paths	One Way Fare $	STOL Demand Daily Person Trips		Round Trips Per Day		Fleet Size	Revenue $/day (000)	Operating Cost $/day (000)	Total Invest $M
Arena Total			6999		36		7	103.0	95.1	81.5
CHI-DET		15.68	3950		21			57.3	52.9	
	Meigs-Detroit City			2290		12				
	Meigs-Mettetal			1660		9				
CHI-CLV		17.67	2238		11			36.6	33.8	
	Meigs-Burke Lakefront			2238		11				
DET-CLV		12.09	811		4			9.1	8.4	
	Detroit City-Burke Lakefront			811		4				

City	Port	Annual Traffic				Capital Costs		Operating Costs	
		STOL O&D Pass (000)		STOL Ops		Airfield $(000)/yr	Terminal $(000)/yr	AF/Term $(000)/yr	Station $(000)/yr
Arena Total		5,109		52,395		582	5,443	951	5,165
Chicago		2,258		23,163		72	2,398	391	2,376
	Meigs		2,258		23,163	72	2,398	391	2,376
Cleveland		1,113		11,411		0	1,182	212	1,115
	Burke Lakefront		1,113		11,411	0	1,182	212	1,115
Detroit		1,738		17,821		510	1,863	348	1,674
	Detroit City		1,132		11,606	126	1,201	215	1,137
	Mettetal		606		6,215	384	662	133	537

Table D-18. Representative STOL System Characteristics
Midwest Triangle
150-Passenger Aircraft ROI = 12%

City Pair	Service Paths	One Way Fare $	STOL Demand Daily Person Trips		Round Trips Per Day		Fleet Size	Revenue $/day (000)	Operating Cost $/day (000)	Total Invest $M
Arena Total			5521		28		6	97.9	77.5	66.4
CHI-DET		18.29	3499		17			59.3	46.9	
	Meigs-Detroit City			2070		10				
	Meigs-Mettetal			1429		7				
CHI-CLV		20.64	2022		11			38.6	30.6	
	Meigs-Burke Lakefront			2022		11				

City	Port	Annual Traffic				Capital Costs		Operating Costs	
		STOL O&D Pass (000)		STOL Ops		Airfield $(000)/yr	Terminal $(000)/yr	AF/Term $(000)/yr	Station $(000)/yr
Arena Total		4,030		41,335		582	4,337	782	3,951
Chicago		2,015		20,667		72	2,148	353	2,115
	Meigs		2,015		20,667	72	2,148	353	2,115
Cleveland		738		7,568		0	798	153	688
	Burke Lakefront		738		7,568	0	798	153	688
Detroit		1,277		13,100		510	1,391	276	1,148
	Detroit City		755		7,748	126	815	156	709
	Mettetal		522		5,352	384	576	120	440

Table D-19. Representative STOL System Characteristics Northeast Corridor 150-Passenger Aircraft ROI = 8%

City Pair	Service Paths	One Way Fare $	STOL Demand Daily Person Trips		Round Trips Per Day		Fleet Size	Revenue $/day (000)	Operating Cost $/day (000)	Total Invest $M
Arena Total			33,156		170		52	512.2	443.7	375.0
NY-WASH		16.23	14,272		73			214.5	185.9	
	Secaucus-College Park			4110		21				
	Mitchell-College Park			4659		24				
	Westchester Co.-College Park			2285		12				
	Secaucus-PG Airpark			3218		16				
NY-BOS		15.45	10,256		52			146.7	127.2	
	Secaucus-Logan			2473		13				
	Mitchell-Logan			1599		8				
	Westchester Co.-Logan			1251		6				
	Secaucus-Bedford			3192		16				
	Mitchell-Bedford			1741		9				
BOS-WASH		21.09	4620		24			90.2	77.9	
	Logan-College Park			2107		11				
	Bedford-College Park			2513		13				
PHIL-BOS		17.70	2602		14			42.6	36.9	
	N. Philadelphia-Logan			2602		14				
PHIL-WASH		13.96	1406		7			18.2	15.8	
	N. Philadelphia-College Park			1406		7				

City	Port	Annual Traffic				Capital Costs		Operating Costs	
		STOL O&D Pass (000)		STOL Ops		$(000)/yr	$(000)/yr	$(000)/yr	$(000)/yr
Arena Total		24,202		248,231		10,636	26,860	5,144	24,448
New York		8,952		91,816		9,818	10,731	1,656	9,158
	Secaucus		4,742		48,638	9,768	6,291	780	4,778
	Mitchell		2,919		29,942	50	3,076	494	3,064
	Westchester Co.		1,291		13,236	0	1,364	382	1,316
Washington		7,406		75,984		768	7,842	1,234	7,127
	College Park		6,234		63,936	384	6,597	1,012	5,941
	PGAirpark		1,174		12,048	384	1,245	222	1,186
Boston		6,379		65,426		50	6,746	1,820	6,654
	Logan		3,662		37,555	0	3,878	1,357	3,797
	Bedford		2,717		27,871	50	2,868	463	2,857
Philadelphia		1,463		15,005		0	1,541	434	1,509
	North Philadelphia		1,463		15,005	0	1,541	434	1,509

Table D-20. Representative STOL System Characteristics Northeast Corridor 50-Passenger Aircraft ROI = 8%

City Pair	Service Paths	One Way Fare $	STOL Demand Daily Person Trips		Round Trips Per Day		Fleet Size	Revenue $/day (000)	Operating Cost $/day (000)	Total Invest $M
Arena Total			25,643		395		69	524.3	460.9	347.3
NY-WASH		21.27	10,283		158			202.5	178.1	
	Secaucus-College Park			2566		44				
	Mitchell-College			2508		39				
	Westchester Co.-College Park			1521		28				
	Secaucus-PG Airpark			1872		29				
	Mitchell-PG Airpark			1216		18				
NY-BOS		20.17	7,881		122			147.2	129.6	
	Secaucus-Logan			1942		30				
	Mitchell-Logan			2265		35				
	Westchester Co.-Logan			916		14				
	Secaucus-Bedford			2758		43				
BOS-WASH		28.16	4,220		65			110.0	96.4	
	Logan-College Park			1171		28				
	Bedford-College Park			1935		18				
	Logan-PG Airpark			1214		19				
PHIL-BOS		23.08	2,201		34			47.0	41.3	
	N. Philadelphia-Logan			995		19				
	N. Philadelphia-Bedford			1203		15				
PHIL-WASH		18.02	1,058		17			17.6	15.5	
	N. Philadelphia-College Park			1058		17				

City	Port	Annual Traffic				Capital Costs		Operating Costs	
		STOL O&D Pass (000)		STOL Ops		Airfield $(000)/yr	Terminal $(000)/yr	AF/Term $(000)/yr	Station $(000)/yr
Arena Total		18,719		575,971		10,168	20,556	4,615	21,621
New York		6,630		203,995		9,584	7,872	1,429	7,662
	Secaucus		3,445		105,993	9,534	4,524	670	3,998
	Mitchell		2,186		67,271	50	2,297	439	2,559
	Westchester Co.		999		30,731	0	1,051	320	1,105
Washington		5,680		174,760		534	5,961	1,118	6,520
	College Park		4,109		126,444	267	4,310	792	4,705
	PG Airpark		1,571		48,316	267	1,651	326	1,815
Boston		5,220		160,621		50	5,476	1,667	6,095
	Logan		3,105		95,536	0	3,252	1,261	3,621
	Bedford		2,115		65,085	50	2,224	426	2,474
Philadelphia		1,189		36,595		0	1,247	381	1,344
	North Philadelphia		1,189		36,595	0	1,247	381	1,344

Table D-21. Representative STOL System Characteristics
Northeast Corridor
100-Passenger Aircraft ROI = 8%

City Pair	Service Paths	One Way Fare $	STOL Demand Daily Person Trips		Round Trips Per Day		Fleet Size	Revenue $/day (000)	Operating Cost $/day (000)	Total Invest $M
Arena Total			32,102		247		43	530.7	464.5	362.6
NY-WASH		17.39	13,510		104			217.5	190.5	
	Secaucus-College Park			3857		30				
	Mitchell-College Park			3211		25				
	Westchester Co.-College Park			2296		17				
	Secaucus-PG Airpark			2508		20				
	Mitchell-PG Airpark			1638		12				
NY-BOS		16.46	10,077		76			153.5	134.6	
	Secaucus-Logan			2383		19				
	Mitchell-Logan			1576		12				
	Westchester Co.-Logan			1290		10				
	Secaucus-Bedford			3088		23				
	Mitchell-Bedford			1739		14				
BOS-WASH		22.74	4,569		35			96.2	83.8	
	Logan-College Park			2085		16				
	Bedford-College Park			2482		19				
PHIL-BOS		18.83	2,529		20			44.1	38.5	
	N. Philadelphia-Logan			1152		9				
	N. Philadelphia-Bedford			1377		11				
PHIL-WASH		14.81	1,417		10			19.4	17.1	
	N. Philadelphia-College			1417		10				

City	Port	Annual Traffic				Capital Costs		Operating	
		STOL O&D Pass (000)		STOL Ops		Airfield $(000)/yr	Terminal $(000)/yr	AF/Term $(000)/yr	Station $(000)/yr
Arena Total		23,434		360,533		10,420	25,801	5,082	24,739
New York		8,609		132,453		9,710	10,189	1,666	9,157
	Secaucus		4,320		66,467	9,660	5,681	743	4,552
	Mitchell		2,980		45,847	50	3,138	524	3,225
	Westchester Co.		1,309		20,139	0	1,370	399	1,380
Washington		7,116		109,484		660	7,489	1,238	7,280
	College Park		5,603		86,201	330	5,882	953	5,665
	PG Airpark		1,513		23,283	330	1,607	285	1,615
Boston		6,269		96,439		50	6,592	1,740	6,771
	Logan		3,098		47,656	0	3,258	1,184	3,348
	Bedford		3,171		48,783	50	3,334	556	3,423
Philadelphia		1,440		22,157		0	1,531	438	1,531
	North Philadelphia		1,440		22,157	0	1,531	438	1,531

Table D-22. Representative STOL System Characteristics
Northeast Corridor
200-Passenger Aircraft   ROI = 8%

City Pair	Service Paths	One Way Fare $	STOL Demand Daily Person Trips		Round Trips Per Day		Fleet Size	Revenue $/day (000)	Operating Cost $/day (000)	Total Invest $M
Arena Total			33,165		128		26	497.0	427.4	350.1
NY-WASH		15.69	14,528		56			211.1	161.6	
	Secaucus-College Park			4188		16				
	Mitchell-College Park			4788		19				
	Westchester Co.-College Park			2270		9				
	Secaucus-PG Airpark			3282		12				
NY-BOS		15.06	10,053		39			140.2	120.7	
	Secaucus-Logan			5655		22				
	Mitchell-Logan			3209		13				
	Westchester Co.-Logan			1189		4				
BOS-WASH		20.39	4,643		18			87.7	75.2	
	Logan-College Park			4643		18				
PHIL-BOS		17.08	2,610		10			41.3	35.5	
	N. Philadelphia-Logan			2610		10				
PHIL-WASH		13.55	1,331		5			16.7	14.4	
	N. Philadelphia-College Park			1331		5				

City	Port	Annual Traffic				Capital Costs		Operating Costs	
		STOL O&D Pass (000)		STOL Ops		Airfield $(000)/yr	Terminal $(000)/yr	AF/Term $(000)/yr	Station $(000)/yr
Arena Total		24,210		186,234		10,838	26,976	5,574	23,454
New York		8,972		69,016		9,944	10,804	1,625	9,026
	Secaucus		4,790		36,849	9,894	6,353	771	4,743
	Mitchell		2,919		22,454	50	3,102	484	3,018
	Westchester Co.		1,263		9,713	0	1,349	370	1,265
Washington		7,483		57,563		894	7,946	1,220	7,070
	College Park		6,285		48,349	447	6,663	999	5,977
	PG Airpark		1,198		9,214	447	1,283	221	1,193
Boston		6,317		48,591		0	6,696	2,308	5,899
	Logan		6,317		48,591	0	6,696	2,308	5,899
Philadelphia		1,438		11,064		0	1,530	421	1,459
	North Philadelphia		1,438		11,064	0	1,530	421	1,459

Table D-23. Representative STOL System Characteristics Northeast Corridor 150-Passenger Aircraft ROI = 0%

City Pair	Service Paths	One Way Fare $	STOL Demand Daily Person Trips		Round Trips Per Day		Fleet Size	Revenue $/day (000)	Operating Cost $/day (000)	Total Invest $M
Arena Total			40,715		210		39	505.7	535.3	455.9
NY-WASY		13.20	17,985		92			219.9	232.7	
	Secaucus-College Park			5328		28				
	Mitchell-College Park			4013		20				
	Westchester Co.-College Park			2923		15				
	Secaucus-PG Airpark			3557		18				
	Mitchell-PG Airpark			2164		11				
NY-BOS		12.54	12,583		65			146.1	154.6	
	Secaucus-Logan			2968		15				
	Mitchell-Logan			2012		11				
	Westchester Co.-Logan			1683		9				
	Secaucus-Bedford			3737		19				
	Mitchell-Bedford			2183		11				
BOS-WASH		17.04	4,815		25			76.0	60.5	
	Logan-College Park			2195		11				
	Bedford-College Park			2620		14				
PHIL-BOS		14.24	2,854		15			37.6	39.9	
	N. Philadelphia-Logan			1304		7				
	N. Philadelphia-Bedford			1550		8				
PHIL-WASH		11.36	2,479		13			26.1	27.6	
	N. Philadelphia-College Park			2479		13				

City	Port	Annual Traffic				Capital Costs		Operating Costs	
		STOL O&D Pass (000)		STOL Ops		$(000)/yr	$(000)/yr	$(000)/yr	$(000)/yr
Arena Total		29,723		304,844		10,636	32,969	6,141	2[illegible],630
New York		11,157		114,433		9,818	13,318	2,056	11,210
	Secaucus		5,690		58,363	9,768	7,508	928	5,545
	Mitchell		3,786		38,828	50	4,005	630	3,915
	Westchester Co.		1,681		17,242	0	1,805	498	1,750
Washington		9,227		94,635		768	9,748	1,519	8,720
	College Park		7,139		73,218	384	7,525	1,154	6,526
	PG Airpark		2,088		21,417	384	2,223	365	2,194
Boston		7,392		75,811		50	7,825	1,959	7,659
	Logan		3,709		38,041	0	3,926	1,375	3,842
	Bedford		3,683		37,770	50	3,899	614	3,817
Philadelphia		1,947		19,965		0	2,078	577	2,041
	North Philadelphia		1,947		19,965	0	2,078	577	2,041

Table D-24. Representative STOL System Characteristics Northeast Corridor 150-Passenger Aircraft ROI = 5.25%

City Pair	Service Paths	One Way Fare $	STOL Demand Daily Person Trips		Round Trips Per Day		Fleet Size	Revenue $/day (000)	Operating Cost $/day (000)	Total Invest $M
Arena Total			35,553		183		34	511.8	472.7	400.6
NY-WASH		15.18	15,376		79			216.1	199.6	
	Secaucus-College Park			4408		2.				
	Mitchell-College Park			5026		26				
	Westchester Co.-College Park			2425		12				
	Secaucus-PG Airpark			3517		18				
NY-BOS		14.45	11,056		57			147.9	136.7	
	Secaucus-Logan			2636		13				
	Mitchell-Logan			1741		9				
	Westchester Co.-Logan			1397		7				
	Secaucus-Bedford			3381		18				
	Mitchell-Bedford			1901		10				
BOS-WASH		19.70	4,686		24			85.5	78.8	
	Logan-College Park			2142		11				
	Bedford-College Park			2544		13				
PHIL-BOS		16.54	2,695		14			41.3	38.1	
	N. Philadelphia-Logan			2695		14				
PHIL-WASH		13.07	1,740		9			21.0	19.5	
	N. Philadelphia-College Park			1740		9				

City	Port	Annual Traffic				Capital Costs		Operating Costs	
		STOL O&D Pass (000)		STOL Ops		Airfield $(000)/yr	Terminal $(000)/yr	AF/Term $(000)/yr	Station $(000)/yr
Arena Total		2,595		266,193		10,636	28,828	5,500	26,087
New York		9,648		98,954		9,818	11,575	1,780	9,813
	Secaucus		5,089		52,196	9,768	6,736	834	5,069
	Mitchell		3,164		32,450	50	3,367	533	3,311
	Westchester Co.		1,395		14,308	0	1,472	413	1,433
Washington		7,958		81,616		768	8,406	1,320	7,546
	College Park		6,674		68,451	384	7,049	1,081	6,238
	PG Airpark		1,284		13,165	384	1,357	239	1,308
Boston		6,730		69,021		50	7,105	1,923	6,997
	Logan		3,873		39,723	0	4,094	1,435	3,997
	Bedford		2,857		29,298	50	3,011	485	3,000
Philadelphia		1,619		16,602		0	1,742	480	1,681
	North Philadelphia		1,619		16,602	0	1,742	480	1,681

Table D-25. Representative STOL System Characteristics Northeast Corridor 150-Passenger Aircraft ROI = 12%

City Pair	Service Paths	One Way Fare $	STOL Demand Daily Person Trips		Round Trips Per Day		Fleet Size	Revenue $/day (000)	Operating Cost $/day (000)	Total Invest $M
Arena Total			29,580		152		29	504.5	401.1	337.3
NY-WASH		17.83	12,562		65			207.4	165.0	
	Secaucus-College Park			3609		19				
	Mitchell-College Park			3038		16				
	Westchester Co.-College Park			2142		11				
	Secaucus-PG Airpark			2292		12				
	Mitchell-PG Airpark			1481		7				
NY-BOS		16.98	9,043		46			142.2	113.3	
	Secaucus-Logan			2218		11				
	Mitchell-Logan			2640		13				
	Westchester Co.-Logan			908		5				
	Secaucus-Bedford			3277		17				
BOS-WASH		23.14	4,499		23			96.4	76.3	
	Logan-College Park			2041		11				
	Bedford-College Park			2458		12				
PHIL-BOS		19.40	2,443		13			43.9	34.8	
	N. Philadelphia-Logan			2443		13				
PHIL-WASH		15.28	1,033		5			14.6	11.7	
	N. Philadelphia-College Park			1033		5				

City	Port	Annual Traffic				Capital Costs		Operating Costs	
		STOL O&D Pass (000)		STOL Ops		Airfield $(000)/yr	Terminal $(000)/yr	AF/Term $(000)/yr	Station $(000)/yr
Arena Total		21,592		221,465		10,636		4,701	22,085
New York		7,886		80,879		9,818	9,435	1,465	8,127
	Secaucus		4,159		42,658	9,768	5,491	688	4,262
	Mitchell		2,613		26,800	50	2,761	447	2,749
	Westchester Co.		1,114		11,421	0	1,183	330	1,116
Washington		6,604		67,737		768	6,977	1,109	6,595
	College Park		5,227		53,612	384	5,524	855	5,182
	PG Airpark		1,377		14,125	384	1,453	254	1,413
Boston		5,834		59,839		50	6,187	1,751	6,072
	Logan		3,741		38,371	0	3,959	1,386	3,873
	Bedford		2,093		21,468	50	2,228	365	2,199
Philadelphia		1,268		13,010		0	1,342	376	1,291
	North Philadelphia		1,268		13,010	0	1,342	376	1,291

GLOSSARY

GLOSSARY

A/C	aircraft
ACMD	Advanced Concepts and Missions Division
ANP	annual number of enplaning (STOL) passengers
AR	aspect ratio
ASM	available seat miles (statute miles)
ATR	Aerospace Technical Report
BATSC	Bay Area Transportation Study Commission
BT	block time
BTPR	Boston Transportation Planning Review
$\bar{c}$	mean aerodynamic chord
CAB	Civil Aeronautics Board
CATS	Chicago Area Transportation Study
CBD	central business district
CO	carbon monoxide
CT	Census of Transportation
CTOL	conventional takeoff and landing (aircraft)
DADZ	Data Aggregation Districts and Zones
DCD	Data Collection District
ΔIOC	port-related indirect operating cost
DOC	direct operating cost
DOT	Department of Transportation

DVRPC	Delaware Valley Regional Planning Commission
EAS	equivalent airspeed (knots)
EPA	Environmental Protection Agency
EPNL	effective perceived noise level
EWR	Newark Airport
FAA	Federal Aviation Agency
FAR	Federal Air Regulations
FPR	fan pressure ratio
GTOW	gross takeoff weight
HC	hydrocarbon
HPY	hours per year
IHSR-1	Interim High Speed Rail System, Option 1
IOC	indirect operating cost
JFK	Kennedy Airport
LARTS	Los Angeles Regional Transportation Study
LAX	Los Angeles International Airport
LGA	LaGuardia Airport
LTO	landing and takeoff
MDW	Midway Airport
NASA	National Aeronautics and Space Administration
ND	number of departures (annual)
NEC	Northeast Corridor

NECTP	Northeast Corridor Transportation Project
NEF	Noise Exposure Forecast
NOACA	Northeast Ohio Areawide Coordinating Agency
NO_x	oxides of nitrogen
Noy	unit used in calculation of PNL which weighs a noise spectrum based on subjective ratings of noise as a function of frequency and amplitude
NP	number of ports (STOL)
NPA	National Planning Association
NPR	nozzle pressure ratio
O&D	Origin and Destination
OASPL	overall sound pressure level
ORD	O'Hare Airport
P&W	Pratt & Whitney
PANCAP	practical annual capacity
Pax	passengers
pers mi	person miles
PK PNL	peak perceived noise level
PNL	perceived noise level
PSA	Pacific Southwest Airlines
PUC	Public Utilities Commission (California)
R	residential (zone)
ROI	return on investment
RP	planned residential (zone)

RPM	revenue passenger miles (statute miles)
S	commercial (zone)
SAE	Society of Automotive Engineers
SATS	Sacramento Transportation Study
SDMATS	San Diego Metropolitan Area Transportation Study
SFO	San Francisco International Airport
SM	statute mile
SMSA	Standard Metropolitan Statistical Area
SPL	sound pressure level
STOL	short takeoff and landing (aircraft)
SWRI	Southwest Research Institute
TALUS	Transportation and Land Use Study (Detroit)
TEB	tons of enplaning baggage
TSC	Transportation Systems Center
TSS	Transportation System Simulation
TWA	Trans World Airlines
UAL	United Airlines
VASCOMP	V/STOL Computer Program
W	manufacturing (zone)
WAL	Western Airlines
Z	unused land (zone)
ZA	airport zone

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